TRANSACTIONS

OF

# THE AMERICAN SOCIETY

OF

# HEATING AND VENTILATING ENGINEERS

VOL. V.

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FIFTH ANNUAL MEETING

NEW YORK, JANUARY 24-26

1899

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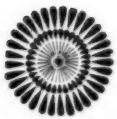

# LII.

# THE AMERICAN SOCIETY
OF
# HEATING AND VENTILATING ENGINEERS.

## FIFTH ANNUAL MEETING.

New York City, January 24, 25 and 26, 1899.

## PROCEEDINGS.

### OPENING SESSION, TUESDAY AFTERNOON, JAN. 24.

The meeting was called to order at 2.35 P. M. on January 24, by the President of the Society, Mr. Wiltsie F. Wolfe.

The Secretary called the roll. The following members and guests were present:

MEMBERS.

Homer Addams.
Newell P. Andrus.
Thos. Barwick.
Reginald P. Bolton.
R. Campbell.
R. C. Carpenter.
Albert A. Cary.
T. B. Cryer.
Geo. B. Cobb.
Frank K. Chew.
B. H. Carpenter.
J. A. Connolly.
Mark Dean.
A. H. Fowler.
Judson A. Goodrich.
John Gormly.
John Hopson.
A. Harvey.
Richard B. Huntje.
Richard Hankin.
Chas. F. Hauss.
Stewart A. Jellett.
H. A. Joslin.
Fred. D. Johnson.
Alfred E. Kenrick.
Wm. Kent.
W. M. Mackay.
Henry C. Meyer.
Wm. McMannis.
Wm. H. McKiever.
Geo. O'Hanlon.
Andrew G. Paul.
D. M. Quay.
H. H. Ritter.
U. G. Scollay.
B. F. Stangland.
P. H. Seward.
L. B. Sherman.
W. F. Wolfe.
B. W. Wilson.
J. R. Wendover.
C. Wadsworth, Jr.
G. H. Weymouth.
F. A. Williams.

GUESTS.

John K. Allen, Chicago.
E. M. Barker, New York.
Edw. Brinley, Brazil.
Wm. Corry, New York.
Henry B. Gombers, New York.
A. T. Henderson, Reading.
W. W. Macon, New York.
E. W. Newman, New York.
Walter Pendleton, New York.
H. N. Reynolds, New York.
P. G. Rimmer, Jr., New York.
J. H. Wagstaff, New York.
E. T. Weymouth, Brooklyn.
W. Webster, Camden, N. J.
T. Webster, Camden, N. J.

The President: Gentlemen, there being more than a quorum present, we will proceed to business. Next in order is the reading of the minutes of the previous meeting.

On motion, the reading of the minutes was dispensed with.

The President then read the following address:

Gentlemen of the Society: I highly esteem the honor and the pleasure of welcoming you to this, our fifth annual meeting. We each and all may feel that since the organization of our society we have done something for humanity and something for the welfare of our fellows, by advancing the profession on the lines of scientific heating and ventilation as against older methods, which practically stood upon a purely commercial basis.

The condition exists that to-day few buildings of any magnitude are being erected or planned without some provision for either alleged or correct ventilation. It rests largely with this society whether we shall insist upon installing only the best, rather than the mere imitation, such as would bring discredit upon us eventually, and as engineers practically eliminate us from the profession, and whether we shall strenuously endeavor to inspire the same views and the same methods in others.

I say this fully understanding that the cost of a good ventilating system, one that is thorough in its design and operation, greatly exceeds that of a make-shift affair, and realizing that the temptation is sometimes strong to slightly cut the requisite apparatus, so that we can compete with those who are without the knowledge to install a proper system. If we have the courage to insist that all apparatus with which we have any connection, either as designers or as competitors for the installation, shall be correct and good, our influence will be quickly felt in an elevated standard everywhere.

Reviewing the work of the past year, we find that the members of our several boards and committees have been untiring in their efforts; and, as the reports of our Secretary, Treasurer, and Board of Managers will show, we are stronger in numbers, stronger financially, and generally in better condition than ever before.

This society, like others of a technical character, contained at its beginning members who really were not actively connected within the lines that would properly make them strictly eligible to full membership to such a society, but as we have progressed and our lines of work have become more clearly defined many of them, finding the true intent and scope of our work, have withdrawn and their places have been filled and our membership increased by the addition of others whose work and qualifications bring them into direct touch

with the society, and whose connection with it adds to its strength and efficiency. Some old members have withdrawn, feeling, perhaps, that they were not in full accord with the technical and professional spirit that animates our active members. Others, more wisely I think, have changed their classification and become associate members. Our associate membership could well be extended by the addition of men who, while not practicing in the engineering lines, are in such sympathy and have such interest in our organization as to impel them to give us the benefit of their efforts and influence. The society as it stands is, therefore, not only improved, as I previously stated, but its standard of scientific attainment is decidedly raised, which is a proper cause for congratulation.

I again extend to you the most cordial welcome, with the fullest conviction that this meeting will be not only interesting, but beneficial to us all.

The Secretary, Mr. Stewart A. Jellett, presented the following report:

REPORT OF THE SECRETARY.

Gentlemen: The reports of the Chairmen, of the Board of Managers and of the Council give an outline of the work done by our society during the past year. From your Secretary, as the principal executive officer, it is natural to look for fuller details, so that every member may be more fully acquainted with what has been done.

When elected Secretary one year ago I accepted the office and entered on the duties with what I supposed was a full understanding of the difficult task I had before me. But any estimate I had formed of what it would be necessary for me to do was greatly below the reality. When your Treasurer's report was read last year it showed a balance on hand of $327.00, with but one bill in his hands unpaid, amounting to $10.14, and we congratulated ourselves on our financial condition. But upon looking over the papers, etc., belonging to the society I found approved bills unpaid amounting to $226.32, and this added to other bills that had not been acted on, together with the expenses of the annual meeting, rent of hall, stenographer, etc., left us to face an indebtedness of $992.34, or $675.34 more than the money on hand. The first duty, therefore, was manifestly to put the society into a better financial condition and this, I am pleased to say, has been done. I at once made a study of the various members' accounts, and reported to the Board of Managers on March 18th that in addition to the amounts paid since the January meeting, there was still due the society for back dues and for dues of the current year (which, according to our by-laws, are payable in ad-

vance), a total of $1,585.00. So that it became evident that it was not due to extravagance that we were delinquent, but rather to the fact that our members were careless in paying their dues. I arranged with our principal creditors to pay off their indebtedness gradually, and at once began correspondence with our membership on the subject of prompt payment of their accounts.

On August 12th I notified the Board of Managers that all back debts had been paid in full, and that there was still due from members a total sum of $900.28. As a number of members who were back in their accounts three and four years did not respond, I reported this fact to the Board of Managers and recommended that their names be dropped from the roll of membership. Each was notified of this action and given thirty days to respond. Eleven members, owing the society $350.00, did not reply even after a second notice had been sent them, and their names were dropped and the sum of $350.00 crossed off the accounts receivable. A number of other members who were delinquent gave satisfactory reasons for their non-payment, and they were allowed additional time. There is still due the society at this writing a total sum of $310.28 from all sources. There is in the hands of the Treasurer $266.40, and there are no bills unpaid and no contracts existing, except the printing of the advance copies and programs of this meeting.

I feel that the society is to be congratulated on its present condition. At the beginning of this year we had a total of 102 members, 6 associate members, and 4 junior members, and 1 honorary member; a total membership of 112. This does not include the new members whose election was announced at the last annual meeting, but who had not qualified at that date. Since that date 11 members have been dropped for non-payment of dues, 5 members and one associate member have resigned, and one member has changed his membership to the associate class. The following new members have qualified since the January meeting, 1898: John S. Farrell, Charles G. Folsom, J. W. Gifford, J. A. Gorton, Henry C. Meyer, Jr., Sam'l G. Neiler, George O'Hanlon, Oliver Schlemmer, E. P. Sparrow, Wm. S. Washburn, Richard Hankin, M. J. Harris, Wm. Kent, A. D. Cross, E. Glantzberg, Wm. H. Bryan, P. Gormly, Benj. W. Wilson, E. H. Murphy, Robert Scott, and Wm. H. Switzer. H. A. Smith and Chas. F. Chase have qualified as associate members, and Henry H. Ritter as junior member, a total of 24. Messrs. Wm. S. Monroe, Wm. H. A. Davidson, Thos. Morrin and Howard A. Loeb (formerly a junior) have been elected to full membership, and

Richard D. Reed and Wm. H. Hill (formerly a member) to associate membership. This makes a net increase of 10 members in the total membership of the society, the total membership at this date being 106 full members, 5 junior members, 8 associate members, and one honorary; a total of 120 members in all classes. This does not include the newly elected members, as they have not yet qualified. We have now a strong membership, and one that is destined to grow steadily.

On account of the limited means in hand and the indebtedness to be canceled, the Board of Managers felt that the society must be run on the most economical basis, and at the second meeting of the Board it was decided that the Secretary should be allowed a sum not exceeding $50 per month to meet all expenses, including clerk hire, postage, stationery, etc. I would report that my expenses for the year for stenographer, clerk hire, postage, rent of post office box, stationery, books, expressage, etc., amounted to a total for the year of $325.95. A number of matters that would be of interest to the members were necessarily abandoned for want of funds.

At the annual meeting January, 1896, when the death of Mr. Hart was announced, some of our members started a subscription for the purpose of assisting in the education of Mr. Hart's son. I found after my election a copy of this subscription list, and learned that the matter had never been closed. The Treasurer had a small amount, one other member had collected a part of it, but a larger part remained uncollected. The total of this list was $170, but three subscribers, whose subscriptions amounted to $15, could not be found. Of the balance, $155, I have collected $130, $125 of which has been sent to Mrs. Hart at Manitou, Col. Five dollars remains in the Treasurer's hands, which will be forwarded to Mrs. Hart.

As a result of my experience in handling the detail of the society's business during the past year, I have reached the conclusion that our Constitution and By-laws can be very much improved. I undertook to formulate some amendments to meet the difficulty, and after very considerable study have outlined what is practically a new set of rules. These I shall present under the head of new business, and at that time will give my reasons for recommending the proposed changes. I would ask your attention to this matter, as I am of the opinion that our society is too much officered as it is conducted now.

In conclusion, I would ask you to give my successor the backing

he most needs, prompt payment of your dues, so that he will feel authorized to undertake new matters of interest to the society at the time they will be most effective.

Fellow members, our society will increase in usefulness to you just in proportion as you take an interest in its affairs. Do not leave everything to your officers, but when you have anything of interest to others let your secretary know of it.

S. A. JELLETT, Secretary.

The Secretary then read the report of the Treasurer, as follows:

REPORT OF THE TREASURER.

Gentlemen: Your Treasurer begs to submit the following report:

| | | |
|---|---|---|
| Cash on hand Jan. 21, 1898, as per last report | | $327.35 |
| Cash received since that date: | | |
| Initiation fees and dues | $1,758.72 | |
| L. H. Hart fund | 120.00 | 1,878.72 |
| | | $2,206.07 |
| Disbursements for the society | 1,765.77 | |
| " " " Hart fund | 135.00 | 1,900.77 |
| Balance | | $305.30 |

Balance in Washington Trust:

| | |
|---|---|
| Hart fund total receipts | $140.00 |
| Paid Hattie D. Hart | 135.00 |
| | $5.00 |

The balance in Washington Trust includes the Hart fund balance of $5.00.

There are no unpaid bills in the Treasurer's hands.

Respectfully submitted,

JUDSON A. GOODRICH, Treas.

Jan. 24, 1899.

Mr. W. M. Mackay read the report of the Board of Managers, as follows:

REPORT OF THE BOARD OF MANAGERS.

Your Board of Managers have held monthly meetings since the last annual meeting, at each of which a quorum of the members has been present. All of the members of the Board have evinced a marked interest in the affairs of the society, frequently coming from a distance to attend the meetings of the Board. At the commencement of the year the financial affairs of the society were found to be in an unsatisfactory condition, there being a large amount of money

due the society by some of the members for dues and a lack of funds necessary to conduct the affairs of the society properly. This was apparently due to lack of method in collecting the dues in the past, and too much credit cannot be given to our present secretary for the very able way in which he has handled this matter and the affairs of the society in general; and by his resigning the office, or declining a renomination, the society loses a most efficient officer, and one whom it will be hard to replace.

Thanks to his efforts, a large amount of outstanding dues has been collected, our total indebtedness has been paid off, and there is a good working balance in the hands of the Treasurer.

There have been no deaths in our ranks during the past year. A few members have resigned, and some have been dropped from the rolls for non-payment of dues, but the end of the year finds us with a larger membership than ever before.

Your Board, after considering other locations, decided on Atlantic City for the summer meeting, and a very successful meeting was held there last July. Your Board would recommend that the summer meetings be continued, as those who attended the last meeting felt amply compensated, both in profit and social enjoyment.

The Board intended publishing a pocket edition of the revised Constitution, By-laws and list of members, but as several members wished to propose some changes to the Constitution and By-laws, it was decided not to publish it until after this meeting.

Your Board, with the assistance of the other officers and the New York members, have arranged for a social reunion of the society to-morrow night, and we believe that something of this sort, which has been found so beneficial in other societies, should be arranged for as part of the proceedings each year.

Your Board has nothing further to report, but would congratulate the society on its membership and financial standing.

W. M. MACKAY, Chairman.

The Secretary then read the following report of the Chairman of the Council:

REPORT OF THE COUNCIL.

The Council has held ten meetings since our last annual meeting. At these meetings it has acted on all the applications received for admission to membership. Most of these were approved, and the Secretary's report will show the changes in membership.

The Council also passed on the various papers for the midsummer

meeting held at Atlantic City, N. J., and for this meeting. The results are left for your judgment.

We would urge on the membership particularly the matter of writing papers on matters of interest to heating and ventilating engineers to be read at our meetings. A very small percentage of our members contribute to our proceedings, and the Council believes that many of our members are in possession of information that would be of great usefulness to their fellow members. It is to be hoped that during the coming year more members will contribute papers. Even if members have had but little experience in work of this kind, let them try it and the Council will attend to the editing.

What is wanted are the ideas and information; the literary form in which to encase them can be provided by the editors. If any member knows of any heating and ventilating engineers that are qualified for membership he should consider it as one of his duties to the society to acquaint them with its aims and purposes. When this is fully understood our membership will be largely increased and the field of usefulness in consequence broadened.

R. C. CARPENTER, Chairman.

The report of the Committee on Compulsory Legislation was read by Mr. Newell P. Andrus, as follows:

REPORT OF THE COMMITTEE ON LEGISLATION.

Gentlemen:

The Committee on Legislation submits the following report of the work done during the last year:

Through the efforts of a former committee there was introduced in the Senate of this State (New York) on January 13, 1898, by the Hon. Albert A. Wray, the following bill:

AN ACT—TO PROVIDE FOR PROPER SANITATION, VENTILATION AND PROTECTION FROM FIRE OF SCHOOLHOUSES AND OTHER PUBLIC BUILDINGS.

*The People of the State of New York, represented in Senate and Assembly, do enact as follows:*

Section 1. Every schoolhouse and other public building hereafter erected in a city or incorporated village within this State shall be provided with proper means for ventilation in such manner that there shall be at all times a sufficient supply of pure air therein; shall be provided with a reasonably sufficient number of proper water-

closets, earth-closets or privies for the use of persons occupying, or admitted to, such schoolhouse or building; and shall be kept clean and free from all noxious smells and gases arising from any drain, privy or other nuisance.

Sec. 2. No wooden flue or air duct for ventilation or heating purposes shall be placed in any schoolhouse or other public building; and no pipe for conveying hot air or steam in any such building shall be placed nearer to any woodwork therein than one inch, unless such pipe shall be properly protected by suitable guards or casing of incombustible material.

Sec. 3. Before the erection, construction, alteration or repair of any schoolhouse or other public building is commenced the person or persons or corporation owning the same shall submit a detailed statement in writing of the specifications, and a full and complete copy of the plans of such proposed building, erection, construction, alteration or repair, which shall be accompanied by his, their or its sworn statement in writing setting out in full the provisions contained in such plans and specifications for the sanitation, ventilation and protection from fire of such schoolhouse or other public building as provided by this act. Such detailed statement, specifications and copy of plans shall be submitted to and filed with the health board, or other officer or officers having like jurisdiction, within an incorporated city where such schoolhouse or other public building is about to be erected, and in all other places, including any city having no officer or officers exercising jurisdiction as a board of health or health officer, such detailed statement, specifications and copy plans shall be submitted to and filed with the State Board of Health. No such schoolhouse or other public building shall be erected, constructed, altered or repaired until such specifications and plans shall be approved in writing by the board of health or officer exercising jurisdiction thereof, to whom such plans shall be submitted as required by this act. The sanitation, ventilation and protection from fire of every such schoolhouse and other public building as provided by this act shall be subject to the inspection of such board of health or other officer exercising like jurisdiction during the progress of such erection, construction, alteration or repair by its or his agents or servants, and shall conform in all things to the reasonable requirements of such board of health or other officer exercising like jurisdiction.

Sec. 4. The word "schoolhouse," as used in this act, shall be taken and deemed to mean any building in which public or private

instruction shall be given to not less than ten pupils at one time; and the words "public building," as used in this act, shall be taken and deemed to mean any building or premises used as a place of public entertainment, instruction, resort or assemblage, or for the purpose of transacting public business of any kind or nature whatsoever where there shall be more than ten persons in any such building at any one time. Provided, however, that this act shall apply only to cities and incorporated villages.

Sec. 5. Any violation of this act or failure to comply with its provisions by any school committee, public officer, corporation or other person whatsoever shall be a misdemeanor.

Sec. 6. This act shall take effect immediately.

This bill was referred to the Committee on Judiciary, of which Mr. Wray was the vice-chairman. There was quite a spirited discussion on the bill, and it was finally laid over for future consideration. There were two Senators who opposed it, their opposition being to the application of the act to incorporated villages.

The bill was introduced in the Assembly by Assemblyman Marshall on January 20, 1898, and referred to the Committee on Affairs of Cities, of which he was chairman. On March 8, 1898, the secretary of this committee received the following telegram from Mr. Wray: "Ventilating bill passed Senate this morning without opposition. Albert A. Wray."

The bill in the Assembly was never reported out of the committee. There has been another bill introduced by the Manufacturers' Association of New York and placed in the hands of Hon. Edward L. Collier, who has consented to take charge of the bill in the Assembly. The following is the bill, as suggested by that association:

AN ACT—To Secure Proper Sanitary Conditions and Proper Ventilation in Public Buildings and Schoolhouses.

*The People of the State of New York, represented in Senate and Assembly, do enact as follows:*

Section 1. Every public building and every schoolhouse shall be kept in a cleanly state and free from effluvia arising from any drain, cess-pool, privy or other nuisance, and shall be provided with a sufficient number of proper water-closets, earth-closets or privies for the reasonable use of persons admitted to such building or attending such schoolhouse.

Sec. 2. Every public building and every schoolhouse hereafter erected shall be ventilated in such a manner that the quantity of foul or vitiated air exhausted or removed shall be positive and independ-

ent of atmospheric changes, and shall not be less than twenty cubic feet per minute for each person; and the quantity of fresh air admitted shall not be less than twenty cubic feet per minute for each person that such public building or schoolhouse can accommodate. The provisions of this act shall be enforced in each village, city, town or county by the board of health thereof. It is made the duty of such boards of health within one year from and after the passage of this act to inspect all the buildings then in use within the meaning of this act, and thereafter to inspect every six months all buildings which shall be applied to the uses herein recited. It is further made the duty of any such board of health, on application in writing of anyone interested, for an inspection of any public building or schoolhouse, to make an inspection within a reasonable time, not exceeding one month after the receipt of such written application; and in every case such inspection shall include the determination of the quantities of air actually removed and introduced, and their efficiency under this act.

Sec. 3. Whenever it shall appear to the proper board of health, upon inspection of any public building or schoolhouse erected prior to the passage of this act, that the sanitary provisions or means of ventilation thereof are insufficient to conform to the requirements of this act, and that from the construction or otherwise such public building or schoolhouse cannot at a reasonable cost be made to conform to the requirements of this act, such board of health shall issue a written order to the proper person or authority directing such sanitary provisions or means of ventilation to be supplied as in their judgment can be accomplished, and the same shall thereupon be supplied by the public authority, corporation or person having charge of, owning or leasing such public building or schoolhouse.

Sec. 4. Any public officer, corporation or person neglecting for one month after the receipt of a written order from the proper board of health, as hereinbefore provided, to provide the sanitary provisions or means of ventilation required thereby shall be punished by a fine not exceeding one hundred dollars. Such action shall not be taken by such board of health if it shall be shown that the failure to comply is unavoidable. and that the trustees, public officers, corporation or person responsible is in good faith preparing to comply with the requirements of the order.

Sec. 5. The expression "public building" used in this act shall include any public building or premises used as a place of public enter-

tainment, instruction, resort or assemblage. The expression "schoolhouse" shall mean any public building or premises in which instruction is afforded to not less than ten pupils at one time.

Sec. 6. This act shall take effect upon its passage.

There has been nothing done in Michigan, so far as we know of. Mr. Andrew Harvey, a member of this committee from that State, hopes to get the matter before the next legislature, if possible.

In Pennsylvania, Mr. A. M. Sloan, of Greensburg, has prepared a very short bill, which will be presented at the incoming legislature this year, a copy of which has been sent to us, his idea being that the shorter the bill is made the easier it will be to have it passed. The following is the bill referred to:

AN ACT—RELATING TO THE LIGHTING, HEATING, VENTILATION AND SANITARY ARRANGEMENT OF SCHOOLHOUSES AND TO THE STATE AND LOCAL BOARDS OF HEALTH.

Be it so enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, and it is hereby enacted by the authority of the same:

Section 1. The State Board of Health shall, within a reasonable time and as often as it thinks it is necessary, issue a circular letter to the local boards of health, giving the best information as to lighting, heating, and ventilation of schoolhouses.

Sec. 2. Local boards of health shall make, under the direction of the State Board of Health, a sanitary survey of each schoolhouse within their jurisdiction and report the same to the State Board. The local boards of health shall in their annual reports refer to the sanitary condition of the schoolhouses within their jurisdiction.

Sec. 3. All schoolhouses hereafter built shall be constructed in respect to lighting, heating, ventilation, and every sanitary arrangement according to regulations furnished by the State Board of Health.

Among bills introduced in the Legislature of the State of New Jersey there was one by Senator Hoffman authorizing the State Department to secure a series of architects' plans for school buildings with special attention to heating, lighting, and ventilation, and requiring that hereafter all school plans throughout the State shall be submitted to the State Department for approval.

Mr. Henry Adams informs the committee that there has been nothing done towards legislation in Maryland for compulsory ventilation. It was too late to take it up during the last session of the

legislature, but it will be brought to the attention of the next legislature, which meets next fall.

Begging for an acceptance of this report, we remain,

Respectfully yours,

B. H. CARPENTER, Chairman.
N. P. ANDRUS, Secretary.
T. B. CRYER,
A. HARVEY,
Committee on Legislation.

The President: The next committee to report is on Uniform Contract and Specifications. Has that committee anything to report?

Mr. D. M. Quay: The committee has not prepared its report, and asks further time.

The President: There is no objection to that. Next is the Committee on Standards. I think Mr. Barron is the only member of that committee at the meeting, and he is not in the room at present. The Committee on Tests is next. None of the committee are here. I think it is safe to assume they will have nothing to report, except to ask for further time.

The President: At the semi-annual meeting the Board of Managers were authorized to appoint a committee to report on the heating and ventilation of schoolhouses throughout the country, as to the general type and methods used. If there are any of the members present ready to make the report we will be glad to hear from them. The resolution, if I remember, was something to the effect that there should be a report from each city of fifty thousand inhabitants or more in which we had a member; that such member should be appointed a committee of his town, and in special instances we combined two or three adjacent places to make up the required fifty thousand.

Mr. Gormly read the following report:

## REPORT ON THE HEATING OF SCHOOLS IN PHILADELPHIA.

By John Gormly, Member of the Society.

Philadelphia heated and ventilated her first school in 1683, by means of open hearth wood fires at each end of every room in a two-story building. The air was changed so frequently that a constant breeze traversed the rooms, mercifully tempered in its effect on the students by the leather clothing then in fashion. We have few schools to-day, after a lapse of two centuries, in which the change of

air is so complete, although we have many heating and ventilating systems in use.

The magnitude of the heating and ventilating problem of to-day may be inferred from the following figures representing the schools of Philadelphia: $12,000,000 invested in school property; $3,686,930 cost of maintenance for the year 1898; 153,000 pupils in the public schools; 40,000 pupils in the parish schools of one denomination. Several denominations have their own schools. We also have several millions invested in private schools and universities. Statistics gathered by the School Teachers' Association show that we have in Philadelphia 14,427 children in schools improperly provided; 8,000 children schooled in rented buildings; 6,000 children schooled on half time; 1,892 children in double classes in one room; 12,000 children from eight to thirteen years of age out of school, having no accommodations. Forty new schools are at present urgently needed; six new school buildings are necessary each year to accommodate the average rate of increase in population. These facts are given that you may have a better general knowledge of the magnitude of the problem of heating and ventilating the schools of our city.

Through the kindness of Mr. Anschutz, Mr. Hammond and Mr. Cassel, respectively, architect, secretary and heating inspector, for the Board of Education, I obtain the following data: We have 447 schools under the management of the Board of Education; 13 of these are heated by direct steam radiation; 38 by direct and indirect steam radiation; 152 by hot-air furnaces. Portions of thirteen of the latter are heated by direct and indirect steam radiation; fourteen school buildings are heated and ventilated by blowers and steam coils.

Four buildings are heated and ventilated by batteries of hot-air furnaces, through which blowers force air to the school rooms. These blowers are operated by gas engines. No electric heaters and no water systems of heating are used in the public schools, although many water-heating plants are located to heat private and parochial schools, with entire success. I am informed that we have some schools heated by stoves; eighteen stoves are said to be in one school. I have seen in many instances eight hot-air furnaces, with as many fires, heating one school building. In very many of our schools heated by hot-air furnaces, and by direct radiation, no provision whatever has been made for ventilation. This applies to schools erected prior to 1870. Your representative visited many schools at the hour of adjournment for the day. In no instance was the air

vitiated to a degree perceptible to the sense of smell. The rooms were ventilated by lowering the top portion of the window sash from 6 inches to 36 inches, corresponding to the outside temperature. Many schools locate a board under the lower window sash; the board has 4-inch perforations, usually two in number, to which are attached sheet metal elbows extending into the room. This device admits air from outside when the top sashes are down enough for heated air to escape. In schools erected about ten years ago, the smoke flues of the several hot-air furnaces are enclosed within brick aspirating shafts. Those in charge of such schools report that they are obliged to open the windows for good ventilation. In fact, it is the general custom in Philadelphia to open windows when good ventilation is desired in schools. The only exception to this rule is the schools heated by blowers. In one such I found windows open during school session, although the engineer assured me he could maintain with his blowers and thermostats a temperature varying but one degree. An effort is made to maintain 70° F. in all school rooms. No tests are made of the purity of the air in schools by the school authorities. We have no law compelling ventilation in schools. We have a law compelling attendance at school. From 24 to 30 cubic feet of air is supplied to each pupil per minute by the fan systems. An effort is made to supply 10 cubic feet of air per pupil per minute with indirect steam and hot-air heating plants. The pupils have nearer 20 cubic feet supplied when the windows are opened, according to custom. An effort was made to obtain from those in charge of all schools such data as they would have concerning the relative economy of the different heating systems. These were not given, for the reason that they were not worked out into percentages. In every case noted the fresh air for ventilation was taken from the surface of the street or from the school yard. No in-take shaft to a point above the roof was discovered. No device for the filtration of air was noticed. Evaporating pans were located in many fan systems to moisten the air supplied to the school rooms. In every instance but one these pans were dry, no automatic device being attached for positive feeding of water to the pan.

In schools heated by hot-air furnaces, with blowers driven by gas engines, much complaint was made of the smell of hot oils, escaping gas, and noisy machinery. The principal noise was caused by loose clutches on the shafting. Much vibration of the rooms above the engine was noticed. The gas supply to the school rooms was rendered very unsteady. Each stroke of the gas engine was plainly

seen in the gas jets of all rooms. In each plant a blower and a fan was attached to the engine—one to force air to the rooms, the other to force the furnace fires. The air was forced through two furnaces in succession before delivery to the rooms. In all the blower systems used the air is delivered to the rooms about 7 feet above the floor line, and in winter is exhausted close to the floor; but in hot weather a register close to the ceiling is used to exhaust the air. In schools heated by direct steam radiation wall coils are located under the windows on the outer walls. These coils are of 1¼-inch pipe and are 7 pipes high, built with headers. Steam is carried at 25 lbs. usually. Non-conductor coverings are not used on the older plants. The boilers are located in the school basements. They are operated by the janitors. The boilers are under the automatic control of diaphragms attached to the draught doors. In schools heated by indirect steam a cluster of indirect radiator sections is located in the basement directly under the room to be heated; air is taken from the street, the yard or the sidewalk at grade; is carried to and through the radiator sections, and distributed to the various rooms through sheet metal ducts or brick flues. No radiation is placed in exhaust ducts to increase their capacity. The result is, the windows are opened for better ventilation.

In fan-heated schools, the fan in every instance is located in the cold-air chamber. Those in charge find no difficulty in feeding oil to the bearings in extreme cold weather. Steam at 30 lbs. is supplied from horizontal tubular boilers located in the basement. No reducing valve is used. Exhaust steam from the engine is utilized in a portion of the heater coils. Condensed steam is collected in a drip tank and pumped to the boilers. In many cases these pumps are not controlled automatically. Heated air is carried in masonry ducts to the base of vertical heat flues. Dampers, controlled by hand, are placed at the base of all vertical heat flues. In plants erected within the last five years these dampers are controlled by diaphragms operated by thermostats. The thermostatic device in use is constructed as follows: A metallic chamber, with flexible corrugated sides, and containing a liquid which vaporizes at 45° F., is placed in each room. The side of this chamber is connected to a lever which operates an air valve controlling 18 lbs. pressure of air. The alternate heating and cooling of the thermostatic liquid thus operates all dampers by controlling the admission or release of air pressure to the diaphragms actuating the dampers. Pressure of business prevented the making of tests and the obtaining of other data.

Mr. Jellett: I have a report from Mr. Mackay, of Newark. And

I would say that I had a letter from Mr. Reck, of Copenhagen, in which he said it was impossible for him to get data on this subject. We had a report from Mr. Tay, of San Francisco, in which he said he would try to get information and give it to this meeting. These are the only ones I have. The following is from Mr. Mackay:

## REPORT ON HEATING AND VENTILATING SCHOOLS IN NEWARK, N. J.

By W. M. Mackay, Member of the Society.

Gentlemen: Having been appointed by your president at the summer meeting of the society, held at Atlantic City last July, as a sub-committee for Newark, N. J., in connection with the general committee appointed to report on the condition of the heating and ventilation of school houses in cities of 100,000 inhabitants and over, in different sections of the country, I would report that Newark is a city of about 250,000 inhabitants, with about 50,000 children of school age, 75 to 80 per cent. of whom attend the public schools. There are about sixty school buildings and annexes in use, accommodating from 125 to 1,200 pupils each. Most of these buildings are old, and the majority of them were reported by the local Board of Health last August as being in an unsanitary condition. In fact, after an examination of all the school buildings in Newark, only four of them were found to be in a perfect sanitary condition.

The heating of these buildings was first accomplished by stoves, room heaters and furnaces, some of which are still in use. As larger buildings were constructed, they were first heated by steam, direct radiation; then by direct and indirect radiation, with natural ventilation. During the past two years, as large additions have been built in connection with some of the older school buildings, the new parts have been heated and ventilated by the fan or blower system; but politics, instead of the most approved methods and materials, have played such an important part in the installation of latter apparatus, that while the designers have charged 5 per cent. for plans, 5 per cent. for supervision and 5 per cent. for guaranteeing the successful operation of the apparatus, there have been numerous complaints of inefficiency, and frequently during the past cold weather some of the new parts of the schools have had to be dismissed on account of lack of sufficient heat. This was at first explained because wrong sizes of pulleys had been placed, but later the trouble has been blamed on the inexperience of the engineer or janitor.

I have been asked to make a report on five school buildings, but as the Board of Education of Newark has confined itself for the past

two years to enlarging old buildings (with the exception of the new high school, which is not yet completed and occupied), I have refrained from doing so, feeling that a fuller description of present methods in any of the buildings would not be interesting to the members or of value as an addition to our records.

Mr. Alfred E. Kenrick: As a member of that committee, I have no written report. As you are all aware, I live in a section where compulsory ventilation is a necessity. I also live in a district, you might say, where they are outrageously extravagant in school expenses. In the little town of Brookline, with less than 17,000 inhabitants, the school property on the first day of January, 1897, amounted to $980,000 invested in school property. Since compulsory ventilation has come into force the school accommodations in the town of Brookline have increased 102 per cent. The scholarship has increased only 33 per cent. As a member of the Committee on Appropriations last spring, I had occasion to go into the subject pretty thoroughly. It costs in Brookline to educate a scholar $43.07, while in the city of Boston it only costs twenty-three dollars and a fraction, and the general average of eighteen places, each with over 60,000 population, was about seventeen dollars. I found that the number of pupils to each teacher in the town of Brookline averaged twenty, while in the general average of the Commonwealth it was forty-two. Our methods of heating and ventilation come under the compulsory laws of Massachusetts. While the city inspectors rather favor mechanical heating and ventilation, it is optional with the party erecting the apparatus as long as he accomplishes the desired result as to what he puts in, but most of the heating and ventilation in the Brookline schools is mechanical. Every one is aware that the matter has been pretty thoroughly discussed.

Mr. John A. Connolly: Are you a member of the School Board of Brookline?

Mr. Kenrick: I am not; no, sir. In Brookline we are governed by the old-fashioned town government. We have our Board of Selectmen. At the annual meeting the only business transacted is the election of the town officers. Then the Moderator of the meeting will appoint a committee of thirty out of the inhabitants to take under advisement all the articles in the warrant and all the appropriations, and that committee reports to the town. Invariably its recommendations are adopted, and the school appropriations, highway appropriations, fire department, police department, and those things are given to different committees to work up.

The President: Are there any other reports from this committee?

Mr. B. Harold Carpenter: I have a partial report from Wilkesbarre and Scranton. In the Wilkesbarre schools there are eight schools using the blower system in connection with the steam, and seven schools using the warm air furnace, and five that are heated by the direct and indirect steam. The blower systems are more satisfactory in Wilkesbarre and are giving better ventilation, and seem to be more satisfactory to the school boards in general. In Scranton I visited the School of Correspondence and the High School and a new building that has just been put up. The School of Correspondence is a building of brick and stone, with halls and stairways of enamelled brick. It is not used as its name might imply for school purposes, for the pupils are scattered far and wide over the country. There are many employes in the building. It was not exactly a school building, but I visited it. It is more of an office building, really. Instruction is given entirely by correspondence, but it had system of heating and ventilation.

The President: Well, if it has a ventilating device, the members would no doubt be glad to hear about it.

Mr. Carpenter: As I said, they had a very satisfactory heating and ventilating plant. I took the trouble to examine it, and was very courteously and kindly shown over the building by Mr. Thompson, who has charge of the heating and ventilating department in the school. The heating is done principally by fan coils, assisted by direct radiation in the corridors and halls and a few of the more exposed places. A blower type of fan in the basement is connected by a belt to an electric motor; the heating is all done by steam, which is supplied from the main in the street. The heating surface is first a tempering coil, over which the air passes before entering the flue. Coming from the fan it passes over the condensing or cooling coil, which is necessary where straight steam is used, and then over twelve stacks of cast iron indirect radiation. These stacks are built of three tiers, one above the other. Each tier is divided into four parts. [Mr. Carpenter then read the report, which is printed in the report of the school-house committee, in the proceedings of the summer meeting at Saratoga.]

The President: There was also appointed a committee at the semi-annual meeting to recommend a method or methods whereby our membership could be properly increased, and naturally, with power to act. If there are any members of that committee here we would be glad to hear their recommendations.

Mr. Kenrick: The committee expect to have a meeting to-

morrow morning, and would ask for further time in regard to that matter.

The President: Gentlemen, you have heard the reports of the several committees, both standing and special. A motion now will be in order to accept the reports and extend our thanks for the information given by the members, etc.

Mr. Kenrick: I move that the reports of the several officers and committees be accepted and placed on file, and the recommendations enumerated by the different committees be referred to the proper committees for their action. I think there are a number of recommendations in the report that the secretary read.

The motion was seconded and carried.

The President: I will appoint as tellers to canvass the vote for officers and committees for the ensuing year Mr. H. A. Joslin, Mr. B. Harold Carpenter and Mr. George B. Cobb. Before proceeding to new business I want to suggest that as our programme is long, and as we never have fully gone through it at any meeting heretofore, that we hold ourselves strictly in line with the subject matter. At our semi-annual meeting a time was set when each was entitled to the floor to discuss any particular subject or paper. That time, by unanimous consent, of course, can be extended to any limit. But by doing that we were enabled to get through our business quickly, and we were held down strictly to the subject under discussion, and I would recommend that a motion be made naming the time that each member should be permitted to have the floor in discussing any subject; of course, subject to extension by unanimous consent. In that way we can probably get through our programme.

Mr. Gormly: I would make a motion, Mr. President, that when members speak on a topic they be limited to five minutes, and that the time may be extended by unanimous consent to a longer period. (Seconded and carried.)

The President: Gentlemen, we will now proceed to new business.

Mr. Kent: I move that the reports of the several committees on school ventilation be printed as a paper, to be distributed for discussion prior to the semi-annual meeting.

(The motion was seconded and carried.)

The President: What other new business is there before the meeting?

Mr. Jellett: If there is nothing to come from the members, I have something to say on the proposed revision of the Constitution and By-laws. There were one or two amendments made at the

meeting last year. I would explain before reading the proposed changes the reasons for making them. It has been found that to try to handle a Board of Managers and a Council and get quorums at all meetings is a pretty difficult thing, when you consider the location of the members. Take our present council: There is a member living in New York, another in Washington, and others in other cities, scattered, so that it is practically impossible to get a working quorum together, and at different times within the past year we have had to conduct our meetings by written authority from members who could not come, appointing some other member to act as a proxy for them. That is not a very satisfactory way of doing business, and a large part of the business of the council has had to be done by correspondence, simply from the fact that we could not get them together. The Board of Managers, counting the President and Secretary, consists of seven members; five of them have been at almost every meeting, I think, that we have had. There have been fifteen meetings since last year, and I think the average attendance has been five. The other two have been at one meeting. They were situated in such a way that they could not get here, so that the five members have done the work, and the other two, simply from the fact that they were fixed in such a way that they could not attend the meetings without very great expense and inconvenience, have left the work to the five. I have, therefore, in looking up the rules, taken this matter into account. I have also taken up the question of membership, the manner of election, and of transfer. We have junior members who, at certain periods, are entitled to full membership, but we cannot give them full membership without a full vote of the society. We have to go through the full printing and description, just as if the man was not already a member. Lately we had the case of a member who was a full member for four or five years. He decided that his business situation was such that he ought not to be a full member, and he asked to be transferred to associate membership. Now, we had to go through that routine fully, in order to transfer him to associate membership. He is certainly eligible to associate membership, if he was entitled to membership. Yet it is possible that a man elected four years ago fully qualified for membership, might be rejected in a vote of that kind by members not personally acquainted with him. The great trouble is that a large number of men know nothing of the man for whom they are voting. In the letter ballots sent out, I have put in the names of the proposers and seconders, thinking that if any individual member wanted more in-

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formation about a man who was a candidate he could get it by writing to the proposers, and this to some extent worked very well. But I felt that some parts of our constitution were too long—did not mean what they should.

Mr. Kenrick: I would make a motion on that subject. I think if there is going to be a revision of the constitution and by-laws we can facilitate matters by having a motion made that a committee on revision of the constitution and by-laws be appointed to take up that matter, and have this whole matter referred to that committee to report to-morrow afternoon. I move that a committee be appointed by the chair on the subject of the revision of our constitution and by-laws, and that the subject matter referred to by Mr. Jellett be referred to that committee.

(The motion was seconded and carried.)

The President: I will appoint Mr. Kenrick, Mr. Mackay and Mr. Jellett as a committee.

There is one thing that would come under the head of "general business" in the report of the committee on compulsory ventilation. It was recommended by that committee that this society endorse the bill which is called the "Manufacturers' Bill." As I followed the bill as it was read it makes the question of ventilation purely mechanical. Now, there are towns, cities and villages that cannot stand the expense, and, if I understand the general principle of the society, we cannot recommend or endorse any manufactured article. The motion accepting the committees' reports and providing that action shall be taken in accordance with their recommendation would compel us to do that.

Mr. Jellett: As I understand that, it simply refers these recommendations to the incoming committees and board of officers for their action.

The President: I do not see how the society can act on that bill. It is simply a mechanical bill—this manufacturers' bill; that is what they call it.

Mr. Kenrick: I can go still further; I think the amount of air supply is not sufficient—twenty cubic feet.

The President: It says "not less." You remember, in Massachusetts, that is how they started.

Mr. Andrus: As a member of that legislative committee, I can state upon pretty good authority that any bill of that kind will not pass in this State. Any bill that will call for any mechanical appliance that will be in the interest of any manufacturer, or any bill that

will call for a State inspector, will never pass the legislature of this State. It would be utterly impossible.

The President: Gentlemen, is there any other new business?

Mr. Quay: The papers are all printed, are they not?

Mr. Jellett: Seven are printed. There are two that are not printed.

Mr. Quay: I move that the reading of the papers be dispensed with and that the points or topics in the papers that either the author or the members wish to discuss be taken up by copy, if that is in order.

The President: I think not. Our programme for the afternoon closes with "new business."

Mr. Jellett: For Mr. Quay's information, I would say that the manuscript of some of these papers did not reach me until Friday last, so that five of the papers I had printed by Wednesday of last week had only been received within a very few days. Mr. Eisert's paper was the first received. That came early. The others came in one at a time. I had the promise of papers, but the men were busy and could not give them to me. As soon as I had five printed I sent them out to all the members. The other two I only got this morning. So I think the papers should be read in the meeting. I doubt if any of the members here have read the last two papers that have come to-day. I do not see how we can discuss a paper that we have not had the time to read. Besides that, I think that some of the members who prepared papers expect to be at the meeting and read their own papers, so that they will be in a position to add to them or answer questions in the discussion. I think it is better to let it go in accordance with the programme, because none of the papers are very long.

The President: I think, gentlemen, we will find here sufficient food for discussion if you take up the several recommendations of the standing and special committees, and by so doing you can guide the incoming committees as to their action, so that it may be in accord with the general ideas of the society. The question will come, What can we do to help enact a law for compulsory ventilation, and what sort of a law shall it be? The committee on membership has a recommendation, so has your council's report, as to how we shall do that. It is a question whether it would be well to discuss it now, in view of the proposed changes in the constitution and by-laws. If you will go over the reports of the standing committees and special committees I think we can have an hour of discussion of profit to

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the society. Is it your pleasure to discuss any point brought forward by the reports of the committees or any new business? If so, it will now be in order. Otherwise, a motion to adjourn will be in order.

Mr. Kenrick: I would like to hear a discussion on compulsory legislation. What are the views of the different members in regard to the bill?

The President: I think that would interest all. Mr. Carpenter has been on that committee, probably, longer than any other member. I think a personal recommendation as to how the thing can best be done and a bill framed that will cover it, so as not to make it a burden, would be interesting, just to start the discussion.

(Mr. Kenrick here took the chair at the request of the president.)

The Chairman: Does any other gentleman wish to be heard on this subject?

Mr. T. B. Cryer: I might state for New Jersey that a year ago we had a bill prepared which went to the Assembly and got lost there. I was told by the Senator who put it in that it would be a hard job to get it passed in New Jersey without some assistance from the society; but he told me if the bill was passed in New York State that he would present it again in New Jersey any time that the bill might be passed in New York.

Mr. Mackay: It seems to me that New York State would be the proper State on which to unite our efforts in getting a bill through. We have had considerably more encouragement from New York State than from any other State. While this report does not show it, we have had two bills—one introduced a year ago by Senator Wray, which passed the Senate and was lost in the Assembly, and then another one this year. Last year the bill was killed on account of there being too many bills. The manufacturers had a bill similar to the present bill for mechanical ventilation. Then there was another individual bill, championed by some one from this immediate vicinity, and then there was our bill. The members of the legislature state plainly that they were misled by some of these bills, and that the only way they could beat the bills they wanted to beat was to beat them all. That is how we happened to get beaten two years ago. This year they were turning everything down, and we were turned down. But having had our bill before the Senate and Assembly twice and having had it passed in the Senate twice, it would seem to me that New York State would be the proper State for us to concentrate our energies in getting a bill through. Having once accomplished it in New York State—and I think it

will be possible to accomplish it in the next legislature—then we could have something to show as the accomplishment of the society. It has not been for lack of effort on the part of the members that we have not accomplished anything tangible. I would move that we, as a society, unite in endeavoring to have such a bill as this society would present passed in Albany. (Seconded.)

Mr. Wolfe: I would move to amend, so that the bill that should carry our endorsement should be more in the nature of the Wray bill than the Manufacturers' bill.

The Chairman: Do you accept that amendment, Mr. Mackay?

Mr. Mackay: I accept it; in fact, that was the intention of my motion. The Wray bill has been our bill for two years, and while Senator Wray is not now in the legislature, we will get some one else to take it up and push it, and I think Senator Wray will give us any assistance that he can in having it pushed.

Mr. Jellett: The motion reads that we concentrate our efforts on New York before we make the attempt anywhere else. Do you think that is wise? Suppose we do not succeed in New York. Must we neglect opportunities elsewhere? I don't think that is right. Two years ago I went to Harrisburg in the interest of a bill before the Legislature of Pennsylvania. I met two Senators and two representatives of the State Board of Health, and discussed with them the whole question. The bill was framed; I was asked to draw it up covering the technical details. I was told frankly by one of the Senators that the bill could not pass. He said, "It will not be reached; I can tell you, there are more bills ahead of it that are of more importance to the men here than your bill, but if you don't have it on the list, you won't have a ghost of a show when the next Legislature meets, and if you fail to enter it now you will go over for four years, on account of the amount of legislation that is being pushed. There are more bills to be killed," he said, "than to be passed, and the orders have been issued to kill them." The bill is, I believe, still on the calendar in Pennsylvania. The Associated State Boards of Health, through the legal committee, are back of it at the present time. Mr. Sloan, chairman of the legal committee of the State Boards of Health, is a man who has had experience in legislative proceedings. He didn't ask the society to come there and push it, but he asks the society to assist him in any way they can. The State Boards of Health have considerable influence, because they are all men that have been in politics themselves. Mr. Sloan has been a member of the Legislature. He is at present, I believe, the president of the Board of Health at Greensburg, Pennsylvania. He

is a member of the Board of Education at Greensburg, so he is in a position to know what is wanted, and he is in personal touch with a large number of senators and others, who tell him they will fight for the bill if there is time when other things that must be attended to are disposed of.

Mr. Mackay: I think Mr. Jellett is right in what he says.

The Chairman: Will Mr. Mackay please put his motion in writing? Is there any other gentleman who wishes to be heard on this subject before the motion is put?

Mr. Mackay's motion was then read, as follows:

"That we, as a society, unite in endeavoring to have such a bill as this society would present passed in Albany."

(The motion was carried unanimously.)

(President Wolfe here returned to the chair.)

Mr. D. M. Quay: Under the discussion of this motion just passed the question of a committee consisting of one, two or three of our members, and their expenses, was spoken of; and whether this is a proper time or not, it would seem if we are going to appoint a committee to second our efforts to pass a bill of that kind, that we should decide in regard to the paying of their expenses.

Mr. Jellett: I would say that the committee on compulsory legislation is one of our standing committees, which will be appointed by our new president, and our by-laws say that all matters of expense must come before the board of managers. Now, the board of managers have authority to pay the expenses of any committee.

Mr. Kenrick: I would like to ask for information, what the procedure is at Albany? In Massachusetts, if you have any bill to present, it has to be presented before a certain time; or, in other words, any bill to be brought before the Legislature of Massachusetts this year has to be presented on the first day of February. No bill is entertained after the first day of February. I don't know whether there is any time limit here in New York or not.

Mr. Connolly: There is this year. All bills are to be presented inside of eight weeks.

Mr. Kent: I would like to ask for information, if anything has been done in New York State about securing the co-operation of the Board of Health of the State?

The President: Personally, I know nothing about the action on that subject.

Mr. Andrus: I think Mr. Wray will be here this evening. If we bring that up, I think we can get some very valuable information from him.

Mr. Kent: I understand the Board of Health in the State of New York is doing excellent work in regard to matters of sanitation, such as the protection of streams, and I think it might take an interest in this. It might be well to see the Consulting Engineer of the Board of Health, who is Professor Landreth, at Schenectady. He is a civil engineer. He advises the board on subjects of sewerage and that sort of thing. We might get his assistance on the matter of ventilation. I think the Governor of the State is a man who is strongly interested in all matters relating to sanitation.

The President: I would say, as a matter of information, that I have had the pleasure of attending three meetings of the State Board of Health, and the trouble would seem to be that, for instance, the State Board of Health has no control over the Board of Health of the city of New York. If the State Board of Health interferes with a local Board of Health, there is trouble on general, broad principles. There would be a clash continually between the Greater New York Board and the local boards. They were not able to see a way out, as far as I know, how they could handle it. The average country member of the Board of Health in a village thinks more of his popularity among his town people, and he really is not a competent judge, as a rule, as to whether a school is ventilated or whether it is not. I think it ought to be in the State Board of Education myself, and let each school commissioner have the district that he represents.

Mr. Kent: I don't see why the State Board of Health cannot get the power to command the purification of the air of a school room in spite of the village Board of Health, just as the State Board of Health now has the power to compel a village to stop polluting a stream. Why cannot the State Board of Health similarly compel a town to stop polluting the air of a school?

Mr. Jellett: In theory it is all right, but it does not work in practice. The stream is already there, and they have not paid for it with their taxes. The school house they have to build and pay for. When it comes to polluting a stream, that generally hits some individual manufacturer, in whom the general town is not interested. I raised that question before this committee at Harrisburg about granting the State Board of Health power of that kind. One of the State Senators looked at me and smiled. He said, "Do you happen to know that the country members in the Legislature outnumber the city members two to one, and their vote counts just the same? Out in a country district the taxes are apparently low—that is, the valuation on which the tax is based. When they build an eight-room school house they are building a pretty

big school. As a rule there are four rooms. They cannot go to work and spend a lot of money for a system of heating and ventilation, and the result is that the local board that would attempt such a thing would be out at the next election. They all look on ventilation of schoolhouses by mechanical means as a city fad." He said, "You cannot get that out of them." I have had some experience myself with the commissioners of several counties where we have acted as engineers. I will recite one of them. The county seat is a town of about thirty-five thousand people. They sent for me to ventilate the court room. I went there and examined the building and met the commissioners. I took up the general question. I mentioned the court house. They said, "No, we don't want the court house ventilated; we want the court room ventilated." I said, "You don't mean to tell me that you want one room in this building ventilated and not the rest?" "That is what we mean. We don't want anything ventilated but the court room." I said, "The sheriff's office, and the county treasurer's office, and the commissioners' office—all of the rest of them need it as much as the court room, and the pipes must necessarily pass through those rooms in order to reach the court room." One of the committee said, "Now, look here: Our only reason for ventilating the court room is, that the judge is kicking about the ventilation, and he is a political power in this county. As far as the ventilation is concerned we commissioners don't care a fig about it. We drive around in our buggies inspecting roads and bridges and get all the ventilation we want. The judge is too big a man to turn down, but we will ventilate the court room and nothing else." That particular county has plenty of money, but I put in a system of ventilation for that court room, passed through all the other rooms, and did not give them any air, by their direct orders.

Mr. Kent: You don't mean to say that the members of the State Board of Health are to be compared with the members of the village boards of health?

The President: No; but the State Board of Health going into a town and undoing or condemning what the local board have done, the local boards having an acquaintance with the people, would, of course, make all the discord they could, as they would be called upon to pay the school tax. "These fellows come down from Syracuse and Albany," they would say, "and run up our taxes."

The President: Is there any further discussion? If not, shall we adjourn and give the tellers an opportunity to prepare the bal-

lots, so that they can announce this evening the result of the ballot?

On motion of Mr. Carpenter, the meeting then adjourned until 8 P. M.

## Second Session.

The second session of the annual meeting was called to order at 8.20 P. M. on Tuesday, January 24, 1899, President Wolfe in the chair.

The President: Are the tellers prepared to announce the result of the election?

Mr. B. Harold Carpenter: We would report as follows:

For President, Henry Adams received 50 votes; J. H. Kinealy, 17; A. E. Kenrick, 1.

For First Vice-President—D. M. Quay, 35; H. D. Crane, 31.

For Second Vice-President—A. E. Kenrick, 47; John A. Fish, 20; Henry Adams, 1.

For Third Vice-President—F. A. Williams, 42; A. C. Mott, 25.

For Secretary—W. M. Mackay, 51; Leroy B. Sherman, 15.

For Treasurer—J. A. Goodrich, 57; J. J. Blackmore, 10.

For Board of Managers—S. A. Jellett, 59; W. F. Wolfe, 54; B. H. Carpenter, 40; Henry C. Meyer, 37; Albert A. Cary, 35; U. G. Scollay, 31; John D. Hibbard, 22; John A. Connolly, 20; Thomas Barwick, 20; William A. Russell, 11.

For Council—Prof. R. C. Carpenter, 63; John Gormly, 46; William McMannis, 44; W. S. Hadaway, Jr., 34; B. F. Stangland, 32; David M. Nesbitt, 31; T. J. Waters, 28; Wm. H. Bryan, 22; Frank W. Foster, 17; George Mehring, 14.

The President: From the report of the tellers, gentlemen, I have to announce that Mr. Henry Adams has been elected President for the ensuing year; Mr. Quay, First Vice-President; Mr. Kenrick, Second Vice-President; Mr. Willliams, Third Vice-President; Mr. Mackay, Secretary, and Mr. Goodrich, Treasurer. The Board of Managers consists of Messrs. Jellett, Wolfe, B. H. Carpenter, Meyer and Cary.

The Council consists of Prof. R. C. Carpenter, and Messrs. Gormly, McMannis, Hadaway and Stangland.

The next order of business for this evening is the reading of a paper by Mr. Eisert, on "The Necessity of Ventilation."

In Mr. Eisert's absence, the paper was read by Mr. Henry C. Meyer, Jr. It was discussed by several members.

The President: The next paper in order is by Mr. B. H. Carpenter, on Heating a Private Residence by a Warm Air Furnace.

Mr. Harvey: Before that paper is read I would like to move that the Secretary be requested to send a message to Mr. Adams, notifying him of his election. Perhaps he may be able to get here by to-morrow morning, if he should get the message to-night.

The President: If there is no objection, gentlemen, the Secretary will be so requested. Mr. Carpenter then read his paper, which was discussed by several members.

The President: An announcement is made on the blackboard that through the courtesy of the New York members, the members of this society are invited to a dinner to-morrow night at the Hotel St. Denis, at half past six. I hope as many of the members as possibly can will join with the New York people there.

Mr. Quay: We passed a motion in regard to the discussion of topics, limiting the speeches to five minutes. I don't know whether that refers to the discussion of papers or not. Shouldn't that five-minute speech be one speech for each member, not to exceed five minutes?

The President: That is the way I understand it, but Mr. Carpenter, I think, had a different view. I do not know exactly whether it applied to papers or not. When it came to the topics of discussion, I was going to take the opportunity of holding speakers down to five minutes.

Mr. Quay: If that does not apply to papers and does not apply to one speech, I would make a motion now, that the limit be so understood—that it also applies to the discussion of papers, and that one speech shall not exceed five minutes.

The President: That is, that no one member can keep the floor more than five minutes on one speech, without unanimous consent? If there is no objection we will consider the other motion as covering that, and a member may occupy the floor five minutes only, excepting by unanimous consent, when his time may be extended. If there is no further discussion on the warm air furnace question for residential work, we come to the topics for discussion.

The meeting then adjourned to the following day at 2 p. m.

## Third Session.

The meeting was called to order on Wednesday, January 25, 1899, at 2.20 p. m., President Wolfe in the chair.

The President: Gentlemen, yesterday there were two committees

who were not prepared to report. The first, on standards, the second on tests, and the committee on uniform contract and specifications requested further time. If all or any of those committees are prepared to report to-day, we had better have these reports now. I would call the gentleman's attention to the resolution of yesterday, which permitted each member the privilege of the floor in discussing any subject five minutes. Inasmuch as we have a good deal of business to do, I shall have to enforce the resolution strictly.

The President: Has the Committee on Uniform Contract and Specifications a report to make?

Mr. Quay: Only two members of our committee are here, I believe. We have conferred on this question and have not made any formal report. I think it might be well to continue this to a later hour.

The President: If there is no objection, the matter will stand over. Is the Committee on Standards ready to report? The Committee on Tests? Mr. Kenrick, we are now prepared for the Committee on Revision of the Constitution.

Mr. Kenrick: Mr. Chairman, I will say that the Committee on Revision of the Constitution and By-laws organized by the choice of Mr. Jellett as chairman of the committee, and I think he is ready to report.

Mr. Jellett: The Committee on Constitution have gone over the proposed form, and I will read the proposed new constitution and by-laws. There are very few copies of the old constitution that are correct. I have one typewritten copy here; if some one wants to follow it while it is being read.

The President: I would suggest as a matter of economy in time that we read only such parts as have been changed.

The several amendments were fully discussed, and the new constitution, printed elsewhere in this volume, was adopted by a unanimous vote.

The following letter, sent to all the members, explains the further action taken by the Board of Managers. At the meeting of the Board of Managers, held on June 10, 1899, the Secretary reported that sixty-five votes had been received in favor of the new constitution, and one vote against it. The board then declared the new constitution adopted and in force from June 10, 1899.

New York, March 31, 1899.

Dear Sir: The officers responsible for the management of your society have felt for some time that the Constitution and By-laws

now in effect did not fully meet its needs. At the fifth annual meeting, held in January last, this matter was given consideration, and a committee consisting of S. A. Jellett, Chairman; A. E. Kenrick, and W. M. Mackay, were appointed to consider the question of revision. This committee reported unanimously practically a new Constitution and By-laws, incorporating a large part of the old rules, but making many radical changes, particularly in the manner of selecting the Nominating Committee, the transfer of junior members to full membership, the centering of all executive business in the hands of a Board of Governors, in place of two separate bodies as it now is. The proposed Constitution was read in detail at the annual meeting, and a vote being taken, it was endorsed unanimously by the members present. A matter of such importance should, however, receive the approval of the whole society; therefore, by direction of a motion passed at the annual meeting, we send you herewith a copy of the Constitution now in use, together with a proof copy of the proposed new one, which you are requested to examine carefully and then vote either "for" or "against" adoption, using the enclosed voting slip, returning vote in the accompanying envelope on or before May 1, 1899.

Should this new Constitution receive practically the unanimous endorsement of our members, it will be at once printed in book form, together with a complete list of members, their business, addresses, etc., and sent to all members.

Kindly give this matter your careful and prompt attention and oblige. Yours very truly,

S. A. JELLETT,
Chairman Board of Managers.

W. M. Mackay, Secretary.

Mr. Jellett: Mr. President, I have one other report here from the Committee on Membership which was handed me a short time ago, which I think might come in now.

REPORT OF MEMBERSHIP COMMITTEE.

Gentlemen—Your committee recommends that an effort be made to obtain advantages for our members by an interchange of courtesies with kindred associations, such as special rates to our members in the purchase of the printed proceedings of other societies, and that our Council be directed to act in this matter.

We also recommend that before our regular meetings there be issued, in the name of our society, invitations which members may

present to desirable parties, extending to them the privileges of the floor at our meetings.

W. M. MACKAY,
R. C. CARPENTER,
A. E. KENRICK,
D. M. QUAY,
ANDREW HARVEY,
JOHN GORMLY,
} Committee.

The President: You have heard the report, gentlemen. What is your pleasure? A motion that the report be accepted and the recommendations adopted would be in order.

Mr. Bolton: I move that the report and the recommendations be accepted. (Seconded and carried.)

Mr. Jellett: I would say that the Board of Managers passed a resolution that engineering colleges and others not on our free mailing list should be provided with copies of our proceedings at the same rate as our new members. A new member coming into our society can get all the back numbers of our proceedings at cost price, and we have extended that same right to the engineering colleges that are not on our mailing list. We have about twelve colleges and engineering societies to whom we send our proceedings. Of course, we cannot extend that thing indefinitely. The society is not rich enough to stand that. Such other engineering associations and colleges as are not on what we call the "free list" can purchase these proceedings at the same rate that our own members can, and we have been acting on that under our rules.

The President: Since our meeting yesterday, when the reports of the committees were in order, there have been two reports—or there has been one presented and another one spoken of—one regarding the schools of England, by Mr. Nesbit, and another one regarding the schools of New York; and as our time is limited, and inasmuch as it is covered by a motion yesterday that the papers and reports regarding school ventilation be published and submitted to the members not later than the semi-annual meeting, if there is no objection those reports will hold over until they are published, and can be discussed at the semi-annual meeting. Mr. Jellett has some drawings here, and memoranda submitted by Mr. Nesbitt, of London.

Mr. Jellett: Gentlemen, these plans came by mail to-day from Mr. Nesbit, of London. These show the method of heating and ventilation of two English schools. There is the plan of the Ellis

avenue school of Leicester, showing the ventilating system, and another set of plans of the Scarcroft school at York. Both of these are completely detailed in color, and have data sheets of exposure, contents, etc., and amount of heating surface. There is a great deal of useful information in them.

Prof. R. C. Carpenter: Is there a committee appointed to report on schools?

The President: At the semi-annual meeting there was a committee appointed, requiring each member residing in a city of one hundred thousand inhabitants or more to report on the typical form of ventilation used in that city, or in the immediate vicinity, and in the appointment of that committee sometimes we had a member in a city of not a hundred thousand; but by including adjacent places that number of inhabitants was covered, and several reports were submitted yesterday, and this one which came to-day and one which we did not have time to act on last night, and it was moved that they be published and distributed to the members not later than our semi-annual meeting. Of course, in our limited time we could not carefully consider the reports.

Prof. Carpenter: Would it be proper to refer these to the Committee on Schools?

Mr. Jellett: The Council has this authority.

The President: I think it was entirely covered yesterday. I think they were directed to have it published. We left last evening without discussing the two topics which were on the programme which might properly come under the head of "Unfinished business," if you care to take them up. First, "The expense of securing good ventilation in cold climates, and the necessity of careful planning to accomplish the required results and minimize operating costs."

The second topic was, "the number of air changes per hour which should be allowed for in the different types of buildings." Both of these topics of discussion are broad.

It was moved and carried that the discussion of topics be suspended at present, and the reading of papers in accordance with the programme be taken up.

The President: The first paper on the programme for to-day is upon "Investigation of a Blowing Fan," by Prof. Carpenter.

Prof. Carpenter: I wish to say in regard to the paper that it was only about one week ago that I was enabled to complete it and to send the proof to our worthy Secretary. The result is that I succeeded in getting the print of the paper, but have not succeeded in

having the cuts made which should go with the paper. The cuts represent all the data. The data, instead of being given in tables, were given by curves. Consequently, I will not be able to take up the paper in detail, but I think if we consider the general conclusions and the general methods, that may be sufficient for the present, leaving for future study the inspection of the cuts.

Prof. Carpenter then presented his paper, which was discussed by several members. After the discussion, action was taken on the paper as follows:

The President: Gentlemen, it appears to me that this paper is so interesting, and is so closely allied to our interests, that I would suggest that possibly a motion that the revised paper be published and sent to the members not later than our semi-annual meeting, so that it might be thought over and discussed more thoroughly at that time, would be in order. We have one report from the Schoolhouse Committee, and the papers are rather late in reaching members for this meeting, and it appears to me that we could not discuss anything to any better advantage than this one paper.

Mr. Kent: I move that this paper be printed, together with such written discussions as may be received, in time for discussion at the semi-annual meeting.

(The motion was carried.)

The President: Gentlemen, is there any further discussion on this paper? If not, we will proceed to the next: "Some Points Regarding the Ventilation and Heating of Tall Buildings," by Henry C. Meyer, Jr., member of the society.

Mr. Meyer's paper was then read and discussed.

The President: If there is no further discussion we will proceed to the next paper, on "The Relation Between Architect and the Heating Engineer," by T. N. Thomson.

The Secretary read the paper, and it was discussed by several members. The following action on the paper was then taken:

The President: Is there any way we can devise to have the gist of the paper and the discussion put in the different trade journals, that is the architectural papers, etc.? That will make the knowledge more general among ourselves.

Mr. Jellett: At the last meeting of the Institute of Architects in Washington this question was discussed of paying for the plans and specifications of heating and ventilating engineers and others, and I am personally acquainted with one of the architects who is on that special committee. I have been doing his engineering work for years and he pays for everything which he has done, and he is one

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of the special committee to whom that question was referred. Now, there has been no objection that I can see to the Council's having this paper put into such shape that it could be sent to Mr. Alfred Stone, the secretary of the Institute. Mr. Stone wrote me some time ago when I took up that question of contract with him that he would be glad at any time that any question affecting the relationship between the two societies was brought to his attention to bring it before the proper committee of their board.

Mr. Kent: I move, then, that the paper be printed with the discussion and circulated as widely as the secretary can conveniently do it. I also move that the paper with the discussion and the whole subject be made an order for discussion at the semi-annual meeting. One of the troubles that the secretary of the society has had is to get papers, to drag papers out of members. Now, at this coming semi-annual meeting of ours we have the school ventilation matter to discuss; we have two or three other things that have already been mentioned. We have already in this meeting found subjects for discussion. So we may have a semi-annual meeting without any new papers, but plenty of old ones, and may have a first rate time at the semi-annual meeting in discussing old subjects.

The President: It seems to me this matter would be better dealt with if you would include in your motion that a committee of one be appointed to make it his special business that the secretary of the American Society of Architects and others be put in possession of these papers in a way that they will be noted.

Mr. Kent: I would do that; with the idea that Mr. Jellett be the committee of one.

Mr. Bolton: I would second that, sir.

The President: It has been moved and seconded that the papers and discussion relative to the paper be published for use at our semi-annual meeting, and that Mr. Jellett be appointed a special committee of one to bring the matter before the American Society of Architects and such other parties as in his judgment may seem best.

(The motion was carried.)

Topic No. 1: "The number of air changes per hour which should be allowed for in the different types of buildings," was then taken up and discussed at some length.

The President: Is there any further discussion upon this topic? If not we may take up the others on the programme for the afternoon. The first is, "discharging water of condensation and blow-offs into drainage and sewerage systems." If there is no discussion upon it, a motion to adjourn is in order.

On motion of Mr. Connolly the meeting adjourned until the following day.

## Fourth Session.

The meeting was called to order at 11:40 a. m. on Thursday, January 26, President Wolfe in the chair.

The President: Gentlemen, yesterday our programme was not fully completed. There remained over simply the topics for discussion, and if it is your pleasure we will leave those for the present and take up the papers which have been prepared and discuss those, and then proceed to the general topics and the general business.

Mr. A. E. Kenrick: Mr. President, previous to taking up the paper, I would like to say that I think the visiting members of this Association are under great obligations to our brother members here in New York, and after the entertainment tendered to us last night, I move that our thanks be extended to the New York members, and especially Mr. Connolly, chairman of the committee.

The motion was carried.

The President: Gentlemen, in the regular order of business there comes first the paper by Mr. William S. Monroe, on "Some Experiments with Centrifugal Fans." Mr. Kent, I believe, has kindly offered to read this paper, Mr. Monroe not being present.

Mr. Kent then read the paper, which was discussed briefly.

The next paper, entitled "Some Formulas for Disk Fans," by Prof. J. H. Kinealy, of St. Louis, was read by Mr. H. C. Meyer, Jr., in the absence of the author, and a discussion by several members followed.

The President: We will now take up our unfinished business and proceed to the discussion of popular questions. There are several committees who have not yet made reports, and I presume are not yet ready. The Committee on Uniform Contract and Specifications have a considerable amount of correspondence and request further time. They are not prepared to make a report.

There is no member of the Committee on Standards here. Mr. Barron was here. I think no member of the Committee on Tests is here. Necessarily those committees will have to turn over the matter to the new committees to be appointed by the incoming administration. At this time it might be well to take into consideration the question of the semi-annual meeting. It has been the custom, heretofore, I think, to express our views upon the subject and by motion refer it to the incoming Board of Managers for action. Are any suggestions to be made about the semi-annual meeting? The

new Board of Managers undoubtedly would be glad of any expression of feeling on the matter.

Mr. William Kent: I would suggest that it be in Massachusetts. The reason is that I think there is more to be learned in regard to heating and ventilation in that State than in any other. They are a little farther advanced in these things than we are here in New York.

Prof. Carpenter: I move that the question of holding a semi-annual meeting of this society as to time and place be referred to the incoming board of managers with power. (Seconded and carried.)

Topic No. 2, "The duty of a heating and ventilating engineer to his client," was then discussed.

This was followed by a discussion of Topic No. 3: "What are the relative advantages of the upward and downward systems of ventilation for audience halls?"

Topic No. 4, "Would it not be in the interest of the purchaser to rate radiators by their heating value based on certain standard conditions?" was then discussed. After the discussion a motion was made and carried referring the subject to the Committee on Standards. The session then adjourned.

## Fifth Session.

The meeting was called to order by President Wolfe on Thursday afternoon, January 26, at half past two.

The President: As in the morning proceedings, if there is no objection, we will first take up the papers and then the topics for discussion so far as possible. The first paper is on "Literature Relating to Blower Fans," by Prof. Carpenter.

Mr. Jellett: This paper is really a schedule of papers and publications on fan data. It is hardly a paper to be read, but it is a paper that ought to go into our proceedings, because it is the result of a great deal of work in collecting this information. To read it would be simply to read the titles, the names of the authors, the dates of publication and the publishers. That is all it is when boiled down. But it is something that we all want, because it brings into compact form information which if we started out to look for would take us the best part of six months to collect. So we want to publish it, but I doubt very much if it would be wise to read it in this form.

The President: I think, if there is no objection, we will let that

lie until Prof. Carpenter arrives. I will go back again as I did this morning to the unfinished topics, and at your option you can discuss or pass them in order. Topic No. 5 is: "Are the capacities of steam traps as given in makers' catalogues of any practical value to the engineer?" What is your pleasure on that topic?

A discussion on this topic followed.

Topic No. 6 was then discussed. It was: "What rules are usually followed in proportioning direct-indirect radiation, and how many heat units are given off per square foot of heating surface per hour under ordinary conditions with this system?"

Prof. Carpenter's paper on "Literature Relating to Blower Fans" was then presented by the author with the following remarks:

Prof. Carpenter: Two or three minutes perhaps might be spent profitably on the paper, and only that. The paper is one which it is entirely unnecessary to read because it is simply a list of literature relating to blower fans that has been compiled. In fact the work was done at my suggestion by two of our young men about to graduate. It represents a good deal of labor and is quite a complete compilation. It is not exhaustive but it gives a great many titles, and gives something of the nature of the various articles referred to, so that one can get a little idea of their subject matter. The literature on this subject is very extensive. I think there are some fifteen pages of manuscript here, averaging perhaps about eight titles to a page, so you can see that the question relating to ventilating fans has excited a great deal of attention in times past. The earliest paper that we quote was written in 1847 by Buckle and is the one referred to in my paper, and in fact is a paper often referred to even at the present time. I would suggest that if other members of the Society can present other titles or papers either different from or earlier than these it would be desirable to have them added to the list, because I think a list of this kind is very valuable for reference.

The following topics were then discussed: No. 7, "General principles to be observed in the installation of the blower system of heating and ventilation."

No. 8, "What is the practical experience as to the loss of heat from hot-air flues, especially when such must be located in outer walls?"

No. 9, "Simple, inexpensive schemes for warming and ventilating small buildings (dwellings, etc.)"

No. 10. "Simple methods of breaking up drafts in forced ventilation work."

General business was then taken up, as follows:

The President: Last night, at the dinner, we received considerable valuable information from Senator Wray relative to legislation, etc., which probably might enable us to talk over the matter more intelligently to-day than during the first day when the matter was discussed, and it has been suggested by a member that this topic be brought before you should you care to discuss it here as a society. Of course last night it was simply a social affair, and will have no bearing on the proceedings of the society in its regular business meeting.

Mr. Jellett: Before that question is opened, I want to ask Mr. Mackay, our new Secretary, to take my place, as I have an engagement and want to make the six o'clock train to Philadelphia later. Gentlemen, I will ask that you give my successor the same encouragement that you have given me.

The President: Mr. Cary, have you any suggestions to make in this matter?

Mr. Albert A. Cary: Mr. President, I listened with great interest to the discussion last evening. If we wish to succeed in our legislative work in getting a bill of this kind passed, we do not want to take it up half-heartedly. We certainly should all put our shoulders to the wheel and make it a matter of personal interest. There have been numberless other movements to pass bills, not only before the State Legislatures but before Congress, and I think by looking around and seeing what others have done in this direction that we can profit by their actions. The Navy Personnel Bill, which was sponsored by the Engineers' Club in this city, was pushed with a great deal of vigor. One of the methods used by them was to issue a circular, not only to their own members but to the members of all the engineering societies, stating just what that bill was, and what its purpose was—that it was a measure to gain a better recognition of engineers in the Naval Service such as they have not enjoyed heretofore. I certainly think that other engineering societies would willingly take hold of such an important matter with us and help us with their efforts. I would suggest that if the funds of our Society are not ample to take this matter in hand properly that a subscription be started; it would not require much from each member, and let us draw up some good strong literature on the subject. Let us send it to all the members of the different engineering societies. Let us, after placing the matter before them, remind each and every one of them that they are the constituents of Assemblymen and State Senators, and when this matter is brought before any State Legislature urge every member of this society and of

all the engineering societies in that State to go to the men they have voted for or those elected from their district and write personal letters to them. If a representative has many letters coming to him from his constituents urging him to interest himself in a good measure he will not be apt to let such appeals go unheeded. Senator Wray has done very good work, excellent work, which we all appreciate, but he could be assisted outside in the way I have outlined. If a number of the members of the Assembly were approached by their constituents, if letters were written to them urging them to take this matter up, to rush it through and to take a personal interest in it, such appeals would surely go a long way towards helping us secure the desired results. As we have started in with this work we do not want to let it lie idle. We should all see our friends and ask them to help us. You live in a certain Assembly or Senate District—go out among your friends there and interest them and convince them that their assistance is needed and give them little blank forms, if necessary, and tell them to fill them out and send them to their Senator and Assemblyman, and if when the next election comes around, and your representative in the Legislature has not taken a proper amount of interest in the matter, it certainly will not act in his favor for re-election, and that is something that a great many of them cannot afford to sacrifice. A measure of this kind I believe can thus be made popular and pushed to a successful issue. I would suggest that some such method be adopted and it will surely result in the quick passage of the bill. With a good man at Albany fathering things as Senator Wray has done, and with our added co-operation, as just described, I feel sure we can succeed in getting the results we desire in this State, and we cannot get them in any other way.

Mr. Davidson: I would like to ask what that bill is, in regard to ventilation; is it schoolhouse ventilation, etc.?

The President: There have been several bills presented, and the most successful one of them so far as it has gone was Senator Wray's, which went through the Senate last winter, but died in the Assembly, providing that the Boards of Health throughout the State should, when in their judgment they found the air in a building unfit for use, order proper ventilation supplied, not especially naming a quantity. Some bills are at Albany now, I believe, providing for a specific quantity. I believe there is one bill called the Manufacturers' Bill. That bill appears to take the form of pushing a special branch of business and would make it compulsory that mechanical ventilation should be used in all cases. That is legislation in favor

of certain manufacturers and that type of legislation is not popular. What we want, as I understand it, and what they have all worked for in New Jersey, Pennsylvania, and New York, is something that as nearly as possible approaches the laws of Massachusetts, with which you are familiar. That bill favors no one excepting the people. What we have been trying to do and hope to continue to try to do until we succeed is to get bills passed in the several States that are in line with the Massachusetts requirements.

Mr. Davidson: I would state that that last bill of Senator Wray was referred to the State Board of Education. I do not know whether they ever took action on it or not. I was up in Albany two or three times and I found that that was where it was resting the last time I was there.

The President: It is rather a complicated affair to handle and we heretofore, as a Society, have done nothing more than see one or two men, and it has been a question if it should not be referred to the incoming Committee on Compulsory Ventilation and left to their judgment. Should we not request one or a few of our members who are conversant with the advantages of ventilation as against no ventilation, and have them go about among the members of the Assembly and the Senate and try to teach and educate them so that they will know they are not legislating for anything excepting the lives and health of their constituents? There are many men in the Legislature at Albany to-day that do not know anything about ventilation. The majority of all legislative bodies I think throughout the country are made up of members more from the country districts than from the city, and the country boys and girls of course are not in schools as long as they are in the city. Their numbers are very much less in each class room. The buildings are not as well built and they get of course a certain or uncertain amount of fresh air from the cracks and leakages and get better air than in the larger towns, and the majority of the Legislature cannot understand the necessity of ventilation, and it is simply a question whether we should send a band of missionaries up to teach them or not.

Mr. Cary: One thing was brought out last evening to which I would like to refer. Somebody remarked that in approaching certain members of the Legislature this argument was met: "There is no necessity for such compulsory legislation." "Our grandfathers and our fathers have grown to be old and they are healthy men." "They went to school in these old-fashioned buildings." "They had no better ventilation than we have to-day and probably not as good." "Why should we do different now with such precedents?" It must

be remembered that the generation of to-day is very differently surrounded from those of two, three or four generations ago. Everything now is moving at a much more rapid pace. The educational requirements from the children of to-day are much more severe and wearing than in the days of our grandfathers. The successful men of to-day are hustlers and they expect their children to hustle all they can to prepare them for the life before them.

We all of us have to hustle if we wish to keep up with the procession to-day. We have to do more work than was accomplished by the preceding generations. The average individual accomplishes more work now than was accomplished years ago, and if he is not supplied with a sufficient amount of fresh air his life is certainly shortened. It is these very conditions that brought this society into existence. You did not, in former generations, find men at the head of big corporations, big trusts or big syndicates, as you find them to-day. We have to provide for the conditions of to-day and not for those of the almost forgotten past.

Mr. Mackay: Is not that fully covered in the resolution passed a few day ago where it was decided that we as a society would unite our efforts in endeavoring to have the bill for compulsory legislation passed in Albany? It seems to me that our society, according to that resolution, must furnish the funds to do it with, and from the information we got from Senator Wray last night it is necessary if we purpose doing anything at this session that we move quickly. Unfortunately our incoming President will not be here to-day to appoint his committees, and it has been decided to defer that matter until he can appoint them by mail. I think that we should urge on him the action that has been taken at this meeting and the necessity of at least appointing that Compulsory Legislation Committee as quickly as possible; also make him acquainted with the fact of the resolution which instructs the society to push matters at Albany in preference to other points.

The President: I think that the motion passed day before yesterday referred this to the incoming committee with power, but it did not give them any ways or means as to raising money. Now, to do that under our constitution they must act with the Board of Managers, because with them rests the expenditure of money, and if I am right in my memory as to the nature of that motion, a motion would be in order to empower that committee to act jointly with the incoming Board of Managers.

Mr. Cary: This is very meritorious, and one of the objects of this society is to secure such compulsory legislation, but last even-



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ing our ex-Secretary, Mr. Jellett, told us how hard he had worked to reduce the debt of the society from $1,500 or more to a few hundred dollars, and, therefore, until we are out of debt and have something in the treasury, I do not think that we should assume any other obligations.

The President: Mr. Cary, excuse me. Not having been present, you did not hear the report. We are free from debt.

Mr. Cary: I am very glad to know it.

The President: And our incoming annual dues would certainly warrant the expenditure of an amount simply to cover the necessary personal expenses of whoever may go to Albany or elsewhere to act as missionaries in the interests of the people.

Mr. Cary: I regret that press of business has prevented me from attending these meetings regularly, and I must admit that all my information concerning this matter was gathered from Mr. Jellett's remarks last evening, and I evidently did not understand Mr. Jellett. I think, however, that this is a movement in which others have an interest with us. Architects, the professional heating and ventilating engineers not included in this society, manufacturers of apparatus, and contractors for heating and ventilation installations—I think that an appeal to them would be well responded to if properly made. We must in our early years practice economy and make our resources a measure for our expenditures, and in endeavoring to secure results costing money we must not let our enthusiasm run away with a cool business-like consideration of these matters. In this case before us I believe that an investment in carefully worded printed matter, stationery and postage, followed by a careful but wide distribution, would bring us all the funds that will be required, with the least possible drain on the society's treasury.

The President: Mr. Cary, I do not think it would be becoming to this society, either to its dignity or to the profession, that we should ask others to help us before we try to help ourselves. Let us try to help ourselves first. Now we have had a committee with their two hands tied, and that could not even buy a postage stamp. Now give them a show.

Mr. Cary: I certainly believe in doing that within reasonable limits.

Prof. Carpenter: I feel personally that we could not make a better use of $100 of our money than in paying the expenses of a committee for this purpose. I do feel that it is a good use to make of any surplus which we may have and I think it ought to be made quickly, and I hope too that the Committee will act in such a way

as to get all the possible benefit of Senator Wray's previous work, and I hope too, above all things, that they won't allow two bills to be introduced, because if a man has two horses to ride he will fall off between them and go down on the ground. But I feel if we act promptly that we certainly stand a good chance of getting some sort of a bill.

Mr. Paul: There is only one thing I would say on this subject. It seems to me that the motion does not state where the money is coming from, or anything of that kind; merely gives them the power to act. The question of where the money comes from can be decided afterwards.

Mr. Chew: I would move that the Committee on Compulsory Ventilation Legislation be empowered to work in connection with the Board of Managers to secure the enactment of a law in New York State and are hereby authorized to pay such expenses as they may deem necessary for the purpose.

My object in making the motion in that way is this: That it has been demonstrated all through this meeting that the one thing this society wants is establishment, and there is nothing that it could do that would give it a standing better than to secure this very law. Already prominent engineers that would make desirable members are looking to us with a certain degree of respect which would be materially increased if, without the assistance of any outside body, we could get such a law passed. The talk which Mr. Wray gave and which the Committee on Compulsory Legislation has given all goes to show that when they so nearly accomplish the enactment of that law without even the expense of a postage stamp to the society, that a very small expenditure of money only will be needed to carry the thing into effect this year. Without being selfish, I would like to have all this glory for the society. I think that the society will accomplish it with just a little financial backing, a very small amount, and I am perfectly willing to leave it to the Board of Managers to listen to the recommendations of the Compulsory Legislation Committee and to give them whatever money they say is necessary.

Prof. Carpenter: I would support the motion. I think that the only possible criticism that might be made of it is the fact that the American society, a National society, is used in getting a special law for a single State. But it seems to me that if we should succeed in getting it the effect of that law in other States would more than repay the members from the other States for their share of the expenditure.

Mr. Chew: My motion is for New York State. Previous to

this motion there had been a motion for this society to concentrate the efforts of the society on New York State this year. It is stated here that the securing of a law in New York State would go very far towards securing a law in Pennsylvania, and I know that so far as New Jersey is concerned, from talking with the New Jersey member of the Committee, that the enactment of a law in New York State would have the same moral effect there. That is the reason I limit it in my motion that the expenditure be in New York State. However, I think that the society has sufficient confidence in the Board of Managers and the Committee, if they deem it necessary to spend another $100 in one of those States, to say go and do it.

Prof. Carpenter: Would there be any objection to leaving out the limitation of New York State in that?

Mr. Chew: I do not see that it would gain much, inasmuch as the society has already expressed its feeling that efforts should be concentrated in New York.

Mr. Davidson: I would state that I do not think there will be any serious difficulty met in getting that bill through. The great obstacle to the last bill, but for which it would have gone through last year, has been removed, and that was a member of this Society who blocked the whole thing.

The President: He is not a member of the Society at present.

Mr. Cary: It would be ridiculous to expect to pass bills in all the States. We have to make a beginning. Why not leave this to the special committee and let them advise with the Board of Managers, if necessary. There is no necessity of mentioning any particular State. We will take one State up and then another. We have to make a beginning, and may be it would sound a little better before members who are not residents of this State if we leave it out. I would suggest that it be eliminated in the motion. I make an amendment to that effect, or endorse Prof. Carpenter's amendment. His is in a little better form.

Mr. Mackay: I think that the only thing that ought to be added to that motion is that we urge on the incoming committee the necessity of immediate action. For Prof. Carpenter's information I would say that the Manufacturers' Bill, which was up two years, is up again this year in New York State, and it was the number of bills that beat us before. There were three bills up the year before last, three bills last year, and now a Senator from Brooklyn has presented the Manufacturers' Bill again, compelling the use of mechanical means for ventilation, and we are not going to have any easy thing of it. It is going to be difficult. But if we take immediate action we are

going to benefit from Senator Wray's best efforts, and I think that common sense with some of the members of the Legislature can help us through. They can see deals in the other bill that are not in ours. I think we should ask for the immediate action of the Committee. Otherwise the efforts of Senator Wray and of the Society will be lost.

Mr. Chew: I can see a reason why the words New York State should be eliminated. It is possible that this committee could prepare literature that could be distributed in New Jersey, Pennsylvania, Michigan, or any other State, and with the permission of the man who supported my motion, I am willing to withdraw those words from it, or to add on, if it seems necessary, the words "immediate action."

Prof. Carpenter: I would like some information if possible regarding the character of the bill. I understood from Mr. Davidson that it is practically the Wray Bill that is now before the Legislature, and that bill, I think, we are pretty certain to get through.

The President: Oh, no. The new bill provides for the introduction of not less than twenty cubic feet of fresh air for each occupant per minute.

Prof. Carpenter: That is the old Massachusetts Law.

The President: No. The Massachusetts Bill does not say anything about quantities, but it is a compulsory bill for mechanical ventilation, because we know that in an ordinary building in summer time, without the fires running, that only by mechanical means can we be absolutely sure of introducing twenty cubic feet per capita per minute. It is moved and seconded that the Committee on Compulsory Legislation be empowered to work in connection with the Board of Managers to secure the enactment of laws for compulsory ventilation, and are hereby authorized to pay the legitimate expenses incurred, and are urged to take immediate action.

The motion was carried.

The President: Inasmuch as neither the new President nor any of the Vice-Presidents are present this afternoon, of course they cannot take the Chair and announce the incoming committees. Mr. Adams is unfortunately ill, but will undoubtedly appoint committees immediately, and notify them by mail. Before the meeting closes I wish to thank you very much for the courtesies you have extended to me since I have occupied the Chair. I congratulate you upon having gone through the programme completely. We have taken up briefly, or otherwise, all the topics provided, and if there is no

further business to come before this meeting, a motion to adjourn is now in order.

Mr. B. Harold Carpenter: I make the motion, if it is in order, that before we adjourn that the society express a vote of thanks for the able manner in which our President, and Secretary, and other officers have conducted themselves.

The President: You will excuse me. That was presented several years ago, and it was assumed that they would do the best they could and a special vote was not necessary.

On motion, the meeting was then adjourned.

# PAPERS

OF THE

# FIFTH ANNUAL MEETING,

New York, Jan. 24, 25 and 26, 1899.

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## LIII.

# NECESSITY OF VENTILATION.

BY H. EISERT.

(Member of the Society.)

What is understood by atmospheric air is a mechanical mixture of gases, of which recent chemical researches give the following as the mean composition of one hundred volumes and of one hundred grains of dry air:

| | Volumes. | Grains. |
|---|---|---|
| Nitrogen | 79.02 | 76.84 |
| Oxygen | 20.94 | 23.10 |
| Carbonic Acid | 0.04 | 0.06 |
| | 100.00 | 100.00 |

Besides these substances, other gaseous matters occur in quantities too small to sensibly increase the bulk of the air, such as ammonia and ammoniacal salts, carburetted and sulphuretted hydrogen, carbonic oxide, sulphurous and sulphuric acid, nitric acid, and perhaps iodine, the quantity and even the presence of which are affected by local and meteorological causes. The air, however, is never found dry, but contains, in addition to the constituents already named, aqueous vapor, the amount of which is constantly changing, according to locality, weather, wind and temperature. By far the most active chemical constituent of the air is oxygen, essential to the existence of animal life, the maintenance of combustion, and many other chemical phenomena. The nitrogen which forms the bulk of the air has few chemical properties of importance, but performs the important part of diluting the oxygen, which, if it occurred alone, would act with too great intensity. Carbonic acid is produced in all processes where carbonaceous matter unites itself with the oxygen of the air, such as in animal respiration, in combustion, in fermentation, in putrefaction, and in similar processes. The green leaves of plants, on the other hand, possess, in presence of sunshine, the power of decomposing the carbonic acid into its elements, absorbing the carbon for their own tissues, and restoring

the oxygen to the air in its original purity. Between the processes above mentioned, on the one hand, and the action of the plants on the other, the quantity of carbonic acid in pure air is kept nearly constant at four volumes in ten thousand volumes of atmospheric air. If it occurred in a much larger proportion, being poisonous, it would become dangerous to animal life; and if it occurred in a much less proportion, the vegetable world would lack its requisite nourishment. In pure air the presence of the other above-named substances need not be considered, as the quantities in which some or all occur are mere traces and difficult to detect in the air itself. A noticeable predominance of any one of these substances, however, would indicate an impure air, unfit for ventilating purposes.

The necessity of constantly renewing the air in closed rooms where living beings are breathing arises chiefly from the vitiating effects produced on air by the products of respiration from the occupants and the products of combustion from burning lights. An additional cause for the vitiation of air is often formed by the allowed or unavoidable presence of gases from chemical processes or dust from mechanical operations. A further necessity for the renewal of the air in a room may arise from the heat generated by the occupants, the illumination or any other cause for an undue increase of the temperature in the room.

### I. PRODUCTS OF RESPIRATION.

By inhaling, the lungs withdraw oxygen, so essential to the support of animal life, from the surrounding atmosphere, and introduce it into the system to convert the products resulting from the disintegration of the muscular, nervous and other tissues of the body into compounds easily eliminated by the excretory organs, as lungs, kidneys, skin, etc. Of these excretions, carbonic acid and watery vapor mixed with other gases and vapors of more organic nature, even minute animal matter, are removed by the lungs with the breath. Hygienic investigations have now demonstrated that the organic products in the breath, with evaporated parts of the products of perspiration, not only are the cause of the disagreeable odor in ill-ventilated rooms, but also are readily absorbed by the minute dust particles ever present in occupied rooms, whence, by putrefying, they become organic poisons. The presence of these poisons in the surrounding atmosphere greatly increases the susceptibility of the human body to disease. As to the quantity of organic products excreted with the breath, it can be assumed with Von Pettenkofer, that it is in proportion to the exhaled quantity

of carbonic acid. The actually produced quantity of carbonic acid, however, depends mainly on the activity of the lungs; this naturally varies with age, sex, occupation, and mode of living. So, for instance, it has been found that an average man in one hour breathes:

| | | | | |
|---|---|---|---|---|
| 16¼ | to 19¾ | cubic feet of air | when | asleep. |
| 19¾ | to 25 | " " | " | at rest in a sitting position. |
| 26 | to 35 | " " | " | when walking. |
| 50 | to 75 | " " | " | " at work or undergoing other muscular exercise. |

Though the specific weight of carbonic acid is 1.529 as compared with atmospheric air, the natural tendency of gases to diffuse and the constant air currents in occupied rooms, even when closed, will cause a nearly uniform distribution of the carbonic acid in the room from floor to ceiling. Carbonic acid is a poison, and when taken into the lungs tends to arrest the vital process; but, like other poisons, it can be rendered harmless by dilution. Even in rooms with no special provision for a positive change of air, it will rarely occur that the carbonic acid exhaled by the occupants and generated by the burning lights accumulates to such an extent as to become dangerous to health, because of the permeability of the walls and the always more or less leaky condition of the windows and doors. However, inhaling of air containing eight per cent. of pure carbonic acid ($8CO_2$,18.4O,73.6N), or four (vol.) per cent. of carbonic acid with the proportionate quantity of organic products of respiration, or 0.08 to 0.2 (vol.) per cent. of carbonic oxide, or two (vol.) per cent. of illuminating gas, will in time cause headache, unconsciousness, or even death.

The excretion of watery vapor by respiration varies widely with the muscular activity of the body and the humidity of the surrounding air.

Valuable data as to the quantities of carbonic acid and watery vapor removed with the breath, under ordinary conditions, were obtained from actual experiments and researches by H. Rietschel and H. Wolpert*, and which are compiled in Tables Nos. I and II.

## II. PRODUCTS OF COMBUSTION.

The products of combustion from fires in stoves, fireplaces, etc., are usually carried off by flues, especially provided for that purpose; but lights, as a rule, burn so that the products of combustion must mingle with the atmosphere. The fire in a stove withdraws air from the room, which is replaced by fresh air from the outside, entering through the crevices of doors and windows or other

*Archive für Hygiene, 1895, Vol. 26, No. 1, page 32.

natural openings, thus causing a certain change of air in the room; whereas burning lights withdraw only oxygen from the surrounding air and replace the same with the products of combustion, chiefly consisting of carbonic acid, watery vapors, and traces of sulphuric acid, ammonia, etc.

Specific data as to the consumption of combustibles and the production of carbonic acid by the burning of lights of various kinds are arranged in Table III, in a convenient form for reference.

As to the allowable limit of the vitiation of the atmosphere by the gases of combustion from various lights, no definite conclusion has been adopted by the profession.

### III. GASES FROM EXPERIMENTAL OR INDUSTRIAL PROCESSES AND OTHER SOURCES.

With few exceptions, all gases that are liable to come into consideration as sources for the vitiation of the atmosphere in occupied rooms, possess a more or less distinct and characteristic odor. The most important of the odorless gases is carbonic oxide, the product of incomplete combustion, because of its highly poisonous character. Under ordinary conditions this gas is rarely produced intentionally where it, possibly, could escape and mingle with the atmosphere, though a faulty condition or management of furnaces and dampers in smoke flues may check the combustion of the fuel so that carbonic oxide is formed, which—when escaping into the room—will greatly endanger the life of any living being therein.

As to the deterioration of the atmosphere in a room by odorous gases, it can only be said that air which is so permeated with any gas that its odor is in the least perceptible on entering the room has lost the required standard of purity. In some cases, however, where chemical or other industrial processes are carried on in the room, and a certain deterioration of the atmosphere therein cannot be avoided, the concentration of produced gases in the atmosphere must not be allowed to reach such a degree as to become in time detrimental to the health of the occupants.

In Table IV are compiled the extreme limits beyond which a concentration in the atmosphere of the most important of such gases should be avoided.

### IV. DUST FROM MECHANICAL OPERATIONS, ETC.

Any deterioration of the atmosphere in occupied rooms by dust from mechanical operations, or other sources, must be considered

separately from case to case, and treated according to the given and required conditions.

### V. GENERATION OF HEAT BY LIVING BEINGS AND ILLUMINATION.

The generation of animal heat by human beings varies greatly with age, occupation, clothing, and the temperature of the surrounding air, and averages about 400 B. T. U. for an adult and about half as much for a child in an atmosphere at the normal room temperature.

The results of some investigations to that effect, with various individuals under different conditions, are compiled in Table V.

Rubner,* in one particular case, found that the total quantity of heat given off in a quiet atmosphere at 63.5° F. by a man with about 24 square feet of skin surface and weighing 176 pounds, amounted to 445.5 B. T. U. in one hour, which was apportioned to the various functions of the body as follows:

| | | |
|---|---|---|
| To respiration | 5.5 B.T U. | 1.29% of total. |
| To muscular exercise (walking) | 8.50 " | 1.90% " |
| To heating of food taken | 7.00 " | 1.55% " |
| To evaporation of water (perspiration) | 92.00 " | 20.67% " |
| To contact with air | 137.50 " | 30.85% " |
| To radiation | 194.75 " | 43.75% " |
| | 445.50 B.T.U. | 100.00% |

The heat given off by electric illumination, which amounts to 12.5-16 B. T. U. for incandescent lights and 2.5-6 B. T. U. for arc lights per candle power per hour, is usually neglected. But with all other types of illumination where the products of combustion from the burning lights mingle with the atmosphere the generation of heat is considerable, especially in large rooms or halls with extensive illumination. Table VI shows the quantities of heat generated by the various kinds of lights per unit of combustible.

In Table VII are also compiled the results of investigations by Rubner as to the apportionment of the heat given off by various kinds of lights by radiation, and the total heat given off by radiation, and by heating the surrounding air and the gases of combustion per candle power.

In the case of electric (incandescent) lighting, Rubner found that per normal candle power, 4 B. T. U. are given off by contact with the air and 10 B. T. U. by radiation.

### VI. THE REQUIRED CHANGE OF AIR.

In order to maintain a certain standard of purity of the atmos-

**Archive für Hygiene, 1895.*

phere in rooms occupied by human beings for any length of time, fresh air must be introduced and the vitiated air removed. The object of the introduction of fresh air is not so much to replace the oxygen used by the occupants in breathing and by the burning light in supporting the process of combustion as to dilute all the vitiating matter that may be produced and mingle with the atmosphere in the room. It is now evident that the quantity of air thus necessary to be changed in a room must naturally depend on the character and effect of the vitiating sources present. The degree of the vitiation of the air in occupied rooms, except in those wherein chemical or dust-producing mechanical processes are carried on, is best determined by the quantity of carbonic acid present, which is proportional to the products of respiration and perspiration from the occupants and the products of combustion from burning lights. It also becomes necessary to consider the heat generated by the occupants and by the burning lights wherever such are present in greater numbers, as the heat then generated may cause the temperature in the room to rise to such a degree as to become uncomfortable, if not detrimental to health. As to the effects of any other vitiating source present, of which data for a direct determination by calculation are not obtainable, proper judgment and, if possible, practical experience in similar cases must be relied upon.

Practically, it can be assumed that, by reason of the diffusion of gases, the carbonic acid is uniformly distributed throughout the room as soon as generated. If it now be required that the contents of the carbonic acid in the atmosphere of the room must not exceed a certain limit, as in schools, etc., the necessary change of air, that is, the supply of fresh air in cubic feet per hour is determined by:

$$A = 10{,}000\,\frac{n \times s}{a - 4}$$

when s = cubic feet of carbonic acid generated by one source (see Tables I and II), usually 0.7 for adults and 0.50 for children in schools;

n = the number of sources present in the room;

a = the allowed limit of carbonic acid expressed in cubic feet contained in 10,000 cubic feet of air;

and the fresh air supply of standard purity contains four cubic feet of carbonic acid in every 10,000 cubic feet. According to Von Pettenkofer, the value a, if possible, should not exceed 7 for rooms in continuous use; though, under certain conditions, especially when the room is occupied for a short time only, a = 10 may be con-

sidered as a sanitary limit. C. Lang and Wolffhugel allow for small rooms even as much as a = 10 to 15.

Von Pettenkofer recommends the same limits for the contents of carbonic acid produced by burning light, but advises that the then necessary change of air be determined separately from that based on the production of carbonic acid by the occupants, and that the results be added.

For rooms in which a large number of people assemble, especially at night, as in theaters, concert halls, assembly rooms, etc., it becomes necessary to determine the necessary air supply so that a certain temperature is not exceeded. The most suitable temperature for the bodily comfort and health in winter time is about 70° F. in rooms continually occupied for any length of time. In rooms occasionally occupied, and then only for a short time, a temperature of 75° F. may be allowed. Near and above burning lights, however, higher temperatures must be tolerated. Supposing now that $H^1$ represents the quantity of heat generated in a room by the occupants in one hour (see Table III); $H^2$ that generated by the illumination (see Table IV); and $H^3$ that quantity of heat which, at the allowed or fixed mean temperature in the room, is transmitted through the walls, windows, etc., in winter time *to* the outside, and in summer time *from* the outside, a quantity of heat equal to:

$$H = H^1 + H^2 + H^3 \text{ in summer time}$$
$$H = H^1 + H^2 - H^3 \text{ in winter time}$$

must be removed by the ventilation. In order to accomplish this purpose, an air supply of

$$A = \frac{H[1 + \alpha\,(t - 32)]}{0.0807 \times 0.2375\,(t - t^1)} \text{ cubic feet per hour,}$$

which, when expressed at the mean temperature t, to be maintained in the room, for t = 70° is equivalent to $A = \frac{H\ 56}{t - t^1}$; $t^1$ represents the temperature of the cooler fresh air on entering the room.

More often it will occur that, in winter time, $H^3 > H^1$ plus $H^2$; then a quantity of heat $H = H^3 - H^1 - H^2$ must be introduced into the room, which requires an air supply $A = \frac{H.\ 56}{t^1 - t}$ expressed at a mean temperature $t = +\ 70°$; but entering the room at the higher temperature $t^1$. (Hot air heating.)

It is not the intention here to enter upon the various features of "Hot Air Heating," which, to a certain extent, has been the

subject of an article published in the issues of 1897, of "Heating and Ventilation."

However, basing the determination of the change of air on a given limit of carbonic acid in the atmosphere in the room, or on the condition that a certain temperature must not be exceeded, requires uniform and constant conditions as well as a positive knowledge as to the purpose and occupancy of the room, the probable number of occupants, etc. Where such statements cannot be obtained, data from experience in similar cases must be applied, and the required change of air in a room for ventilation is usually expressed as a fraction of the cubic contents of the room.

As a rule, rooms very little occupied, require the air changed but once in one hour, a change which must be increased as any additional conditions require. Under ordinary conditions a change of air equal to 1.5 to 2 times the cubic contents of the room is quite sufficient. But in rooms where odors are liable to develop, as in toilet rooms, etc., the air should be changed four to five times in one hour.

In providing a certain air supply to a room, it must always be borne in mind that the first principle of ventilation is to change the air in a room without causing a draught. Practical experience has now shown that, under ordinary temperature conditions, the air in an occupied room cannot well be changed more than five times per hour without causing annoying draughts.

Thus, whenever the given or assumed conditions in a room require the air to be changed more than five times in one hour, these conditions must be modified accordingly. A case of this character is typically illustrated by a much exposed room to be heated by introduced air only, especially when the temperature of the entering air is limited. In rooms with little exposure and provided with electric or very limited gas illumination, satisfactory results can be obtained in nearly all cases; but rooms extensively illuminated by gas must be very high and the lights so arranged as to be sufficiently above and from the occupants, as no change of air will overcome the annoyance caused by the radiated heat from the burning lights. The heated air above the burning lights should be removed as directly as possible. It is advisable in all such cases to determine the air suppply for the occupants separately from that for the burning lights and, when possible to do so, arrange the fresh and foul air ducts accordingly. In such cases a higher temperature must be allowed for the space above the burning lights than that intended for the immediate vicinity of the occupants. For the

occupants of the spaces near and above burning lights, as in theaters, etc., a sometimes disagreeably high temperature cannot well be avoided, unless cooled air is introduced; and even then, only conditionally. As a rule the requirements in regard to the limit of carbonic acid in the atmosphere in a room can readily be complied with, unless the room is unduly crowded. In case a certain overcrowding of a room cannot be avoided, a larger contents of carbonic acid might be tolerated; but not more than 0.15 per cent. when occupied by healthy people; for sick rooms the *extreme limit* of 0.07 per cent. must not be exceeded.

TABLE I.

Generation of carbonic acid by human beings in cubic feet per hour. (H. Rietschel.)

| Subject. | Age. | Weight. | Carbonic acid. | Remarks. |
|---|---|---|---|---|
| Laborer | 28 | 160 | 1.2810 | At work. |
| The same | ..... | ..... | 0.7982 | At rest. |
| Man | 28 | 180 | 0.6569 | In average. |
| Woman | 35 | 185 | 0.6004 | " |
| Boy | 16 | 127 | 0.6145 | " |
| Boy | 9½ | 48 | 0.3638 | " |
| Girl | 17 | 123 | 0.4546 | " |
| Girl | 10 | 50 | 0.3426 | " |

TABLE II.

Generation of carbonic acid and watery vapors by human beings in one hour. (H. Wolpert.

| Subject of test. | | | At work. | | | | | | At rest. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Occupation, etc. | Age. | W'gt. | Duration of test. | Tem. of surro'nding air. | Hum | Carbonic acid. | Water. | Remarks. | Duration of test. | Tem of surr'nding air. | Hum | Carbonic acid. | Water. |
| | Yrs | Lbs | Hrs | Deg F | P. C. | Cu. ft | Gr'ns | | Hrs | Deg F | P. C. | Cu. ft | Gr'ns |
| Laborer | .... | 154 | 4 | 45 | 81 | 1.515 | 2.030 | dynamic effect about 30 foot pd's per sec. | 4 | 69 | 20 | 0.551 | 1.120 |
| The same | .... | .... | 4 | 77 | 47 | 1.423 | 8.050 | | 4 | 78 | 26 | 0.586 | 2.555 |
| The same | .... | 161 | 3 | 55 | 84 | 1.459 | 2.555 | | .... | .... | .... | ..... | ..... |
| The same | .... | .... | 4 | 62 | 59 | 1.800 | 4.970 | | .... | .... | .... | ..... | ..... |
| The same | .... | .... | 4 | 63 5 | 87 | 1.572 | 3.255 | | 5 | 63 | 61 | 0.628 | 0.735 |
| The same | .... | .... | 4 | 66 | 83 | 1.508 | 4.000 | | .... | ..... | .... | ..... | ..... |
| Dressmaker (hand sewing) | 28 | 97 | 4¼ | 63 5 | 73 | 0.911 | 1.925 | | 4¼ | 63 5 | 63 | 0.805 | 1.820 |
| The same (mac'ne) | .... | .... | 4¾ | 66 | .... | 1.102 | ..... | | .... | ..... | ..... | ..... | ..... |
| Clerk | 25 | 141 | 4¼ | 64 | 44 | 1.331 | 1.768 | | 3½ | 69 | 29 | 1.141 | 1.960 |
| Lithographer | 25 | 141 | 3 | 66 | 41 | 1.373 | 1.978 | | .... | .... | .... | ..... | ..... |
| Draughtsman | 25 | 141 | 3¾ | 69 | 41 | 1.614 | 1.978 | | .... | .... | .... | ..... | ..... |
| Tailor | 26 | 108 | 4¼ | 69 | 30 | 1.127 | 1.936 | | 3¾ | 66 | 30 | 0.922 | 1.558 |
| Machinist apprentice | 15 | 95 | 5 | 66 | ..... | 1.503 | ..... | | 4¾ | 63 | ..... | 1.109 | ..... |
| Shoemaker (light work) | 24 | 136 | 4 | 66 | 46 | 1.639 | 2.135 | | 4 | 60 | 60 | 1.112 | 0.978 |
| Sh'mkr.(h'v'y wk) | 25 | 103 | 4¼ | 71 | 46 | 1.992 | 3.395 | | 4½ | 63 at s leep | ..... | 1.049 | ..... |
| Man of aver'ge age | .... | 167 | .. | ... | ..... | ..... | ..... | | 10 | 66 | 63 | 0.412 | 1.365 |
| Man of aver'ge age | .. | 154 | .... | ..... | ..... | ..... | .... | | 8 | 70 | 23 | 0.449 | 2.100 |

TABLE III.

Consumption of combustibles and generation of carbonic acid by burning lights per normal candle power per hour. (Röttinger.)

| Sources. | Consumption of Combustible. | | Carbonic Acid per C. P. in. |
|---|---|---|---|
| | Per light. | Per C. P. | Cubic ft. per hour |
| | per cubic ft. | per cubic ft | |
| Gas: Fishtail burner | 0.883—2.473 | 0.802—0.527 | 0.494—0.304 |
| " " " | 2.823—6.710 | 0.392—0.374 | 0.226—0.215 |
| " Argand " | 3.532—4.243 | 0.445 | 0.254 |
| " " " | 4.944—8.128 | 0.350—0.300 | 0.201—0.173 |
| " Welsbach* " | 3.178—5.297 | 0.053—1.024 | 0.030—0.057 |
| | | gallons | |
| Petroleum, large, round burner | | 0.00066 | 0.112 |
| " small, flat | | 0.00198 | 0.335 |
| | | ounces | |
| Wax candle | | 0.271 | 0.417 |
| Paraffine candle | | 0.324 | 0.459 |

*New Welsbach burner = 56 normal candle power; pressure of gas from 0.8 to 2.75 inches of water.

TABLE IV.

Dangerous concentrations in the atmosphere of the most important gases in cubic feet per 100 cubic feet of air.

| Gas or vapor. | Detrimental Effect Occurs. | | |
|---|---|---|---|
| | in several hrs. | in ½ to 1 hour. | immediately. |
| Iodine vapors | 0.00005 | 0.0003 | ..... |
| Chlorine " | 0.0001 | 0.0004 | 0.005 |
| Bromine " | 0.0001 | 0.0004 | 0.005 |
| Muriatic Acid vapors | 0.001 | 0.005 | 0.015 |
| Sulphurous " | ..... | 0.005 | 0.05 |
| Sulphureted-hydrogen vapors | ..... | 0.02 | 0.06 |
| Ammonia " | 0.01 | 0.03 | 0.35 |
| Carbonic oxide | 0.02 | 0.05 | 0.20 |
| Carbonic acid | 1.00 | 8.00 | 30.00 |
| Carbureted-hydrogen vapors | ..... | 6.56 grains | 437.00 grains |

TABLE V.

Generation of (animal) heat by human beings.

| Authority. | Subject. | Temp. of surrounding air | B. T. U. per hour |
|---|---|---|---|
| Rubner | Infant | 70° | 64 |
| " | Adult at rest | 70° | 380 |
| " | " light work | 70° | 467 |
| " | " heavy " | 70° | 554 |
| " | Old man | 70° | 356 |
| Barrol | Child 6 years old | 70° | 242 |
| " | Man 29 years old | 32° | 006 |
| " | The same | 70° | 444 |
| " | Man 59 years old | 70° | 511 |
| " | Woman 32 years old | 70° | 483 |

TABLE VI.

Generation of heat by burning lights, in British thermal units per unit of combustible.

| Combustible. | Unit. | B. T. U. |
|---|---|---|
| Illuminating gas | Cubic foot | 580 to 600 |
| Petroleum | Gallon | 150,000 |
| Wax | Pound | 18 540 |
| Sperm (paraffin) | Pound | 17,410 |

TABLE VII.

Proportion of the heat given off by radiation alone to the total quantity of heat generated by burning lights, in B. T. U. per normal candle-power. (Rubner.)

| Sources. | Radiated Heat. | For heating air and gases of combustion. | Total. |
|---|---|---|---|
| Gas, Fishtail burner | 32 | 281 | 313 |
| " Argand " | 28 | 170 | 198 |
| " Welsbach " | 6 | 26 | 32 |
| Petroleum | 42 | 116 | 158 |

DISCUSSION.

The President: The paper is open for discussion. It seems to me that there must be some questionable points in it. Mr. Kenrick, in Massachusetts practice, hasn't it been demonstrated that the air can be changed in a room in about seven minutes, without a draught?

Mr. Kenrick: I think it can, Mr. President; in fact, I know it can.

The President: This is too good a subject to let it pass by unnoticed. This paper has certainly had considerable study. We ought not to pass it by without weighing it a little.

Mr. Kent: The author says in regard to rooms lighted by gas, that the heated air above the burning lights should be removed as directly as possible. I think in modern ventilation the idea is that all air should be introduced about seven or eight feet above the floor, and the products of respiration taken out near the floor level. If the plan of the paper is followed, we would have to have an outlet above the gas-lights. I would like the opinion of members as to what they would do in such a case as that, whether they would have two outlets for the air, one at the ceiling to let out the products of combustion and the gases and the heat, and one at the floor, to take out the products of respiration, or what they would do in this matter. It seems to be contrary to modern practice.

The President: Two ordinary candles are supposed to vitiate as much air as one man can, and an ordinary kerosene lamp of the old style, with a half or three-quarter inch wick is equal to two men. A four-foot gas burner is equal to eight men, and I presume the calculations on your air supply would be so figured.

Mr. Connolly: I would state, for Mr. Kent's benefit, that in churches, etc., the question of carrying off the heat from a large number of gas jets and the question of heating and ventilation are two different subjects; and it is generally secured from the top, as Mr. Eisert suggested. I have seen a case where it was tried in connection with the heating and ventilation. Dampers were placed in the tin conducting pipes from the gas jets, and one evening the

janitor forgot to open the dampers. The consequence was that at the evening service the solder thawed out, as it were, from the joints, and fell on the bald-headed men.

The President: Well, it is a common practice to have the conducting pipe leading up from a lighted chandelier, etc.

Mr. Connolly: I would like to ask Mr. Kenrick a question. As I understand this ventilating scheme in Massachusetts, they do it with the thermal system—no mechanical devices at all, and they change the air seven times an hour. Is it not so?

Mr. Jellett: Once every seven minutes.

Mr. Connolly: Nine times an hour.

The President: A room can be filled with air and emptied once in every six minutes and a half, without creating a draught, if it is over nine feet high.

Mr. Connolly: Well, I would like to ask Mr. Kenrick what is the temperature outside under those conditions, when he can move it eight or nine times an hour. Is it at zero, or forty degrees, or what?

Mr. Kenrick: In the building that I have in mind, a test was made by the State inspectors. The temperature outside was ten above zero, as nearly as I can recollect.

The President: I think the question of temperature would not enter into the question at all. It can be done by mechanical means, at any time. In the gravity system in Massachusetts, those results can be attained at any time, if the difference between the inside and outside temperature is not less than forty degrees.

Mr. Connolly: Oh, not less than forty?—Well, I question that. I am sorry to disagree with the President.

The President: I am simply giving you the standard of the department. It is not mine. It is perfectly safe to give a guarantee. You can move that amount of air by gravity without mechanical means when the difference between the inside temperature and the outside is not less than forty degrees. Of course, when it is more, you can move more air.

Mr. Henry C. Meyer, Jr.: I think that Mr. Eisert deserves the thanks of this Society in that he has, perhaps intentionally, brought out the value of the heat unit method of determining the size of heating and ventilating plants for these large buildings, in which the heating effect of lights and human beings are taken into account. He shows in one part of his paper that the heating effect of one person amounts to about as much as two square feet of direct radiation, and I know that in the calculations for the ventilation of at least one large building in this vicinity it was found out when taking into

account the heating effect of the gas jets and the people in the room that it was necessary to admit that air considerably below seventy degrees, or at so low a temperature that it would make an unpleasant draft. So it was necessary to reverse the system by admitting the cool air at the top of the room to be ventilated, instead of at the bottom, as originally intended. If they had attempted to supply the air through the floor and take it out through the top, with the air at such a low temperature, the system would have been a failure.

Mr. Jellett: We all know that in theatre heating and the heating of audience halls and assembly rooms of different classes the required amount of heat varies greatly with the occupancy. But you cannot design a building on the assumption that it is always going to be filled; so that this is more particularly valuable as a means of regulating heat than it is as a basis for your calculations in designing your heating system. Now, I have in mind an assembly room, or, as you might call it, an operating amphitheatre of a medical college, which has, if I recollect rightly, about 65,000 cubic feet of space. The seats are pitched very sharply, and they seat 520 men. The system is designed to give them a thousand cubic feet of air per hour for each occupant. That gives 520,000 cubic feet. In proportion to the amount of space, it means eight changes per hour. The ceiling is, I think, about thirty-two feet high. The air is brought in pretty well up from the floor, I think about twenty feet, and the exhausting is done under the tiers of seats, and that room is controlled by one thermostat, hung in the middle by a flexible cord, so as to take the average of the room. We found that if we hung it below, the men on the upper tiers got too much heat. If we hung it above, it was too cool on the floor where the professor was operating, particularly as he frequently had to bring in living subjects to illustrate a point, and the subject was stripped, and it required a good temperature at the operating platform. When the system was first started, I suggested to the professor in charge that we set the thermostat at 65. He said, "That is entirely too low; we cannot allow anything of the kind." I said, "You have 500 men here, and the average attendance is 475 during the lectures, and that will soon bring it up." He said he couldn't have anything of the sort; that he must have 70; that he preferred 72; he compromised at 70. The first day the temperature ran to 78 in fifteen minutes after the men came in. The lecture began, and was all over in about an hour and a quarter. Then he consented to set it down to 66. We kept on setting it down, until we got it down to 62. Having it at 62 before students began to come in, we could maintain 70 with the average

XUM

attendance of 460 to 480 men, so that the radiant heat from the bodies of that number of men brought up the temperature about 8 degrees inside of fifteen minutes, because it was about fifteen minutes after the opening of the doors that the thermometer reached that point, when the thermostat cut off the heat and gave us the cooler air. The thermostat operated to cut off certain coils, which dropped the temperature of the incoming air and kept it at the desired point. I think that Mr. Eisert's tables are very useful in the way of giving an estimate of about what to do in regulation in an audience room after the people get there, but you cannot design a system on the assumption that they are coming.

Mr. Meyer: You have to design for the maximum and minimum conditions, though. If you put it in the other way it would be a failure.

Mr. Jellett: That is particularly useful if you have a regulating system and know what your adjustment is to be.

The President: I think you will find there are very few theatres but what turn the heat off immediately after the house is filled.

Mr. Jellett: Yes, and put in cool air, sometimes.

Mr. Andrew Harvey: I would like to ask Mr. Jellett how many cubic feet of space would the bodies of 450 men take up in that room?

Mr. Jellett: I should judge about 3,000 out of the sixty odd thousand that the room contained.

Mr. Harvey: I mean, how many cubic feet of the space would their bodies occupy?

Mr. Jellett: That is what I mean, about 3,000 cubic feet they would displace. I think that the average man does not displace much more than six cubic feet. I never have figured it out at all. It depends somewhat on the size of the men.

Mr. Wadsworth: I would like to call attention to two statements that I think are open to question. On page 58 he says, speaking of carbonic acid, "If it occurred in a much larger proportion, being poisonous, it would become dangerous to animal life." The statement is questionable, in that it has not yet been proved that carbonic acid—properly speaking, carbon dioxide—is a poison. It produces its effect by asphyxiation—by strangulation. It does not act as a poison in any sense at all.

On page 59 he makes the same statement again, that "carbonic acid is a poison, and when taken into the lungs tends to arrest the vital process." But it does not arrest the vital process by poisoning.

The President: I think it is generally understood in making a test that carbonic acid, so-called, or carbon dioxide, is simply taken as a factor of the general impurities that exist in the air. The normal atmosphere contains four parts in ten thousand. If it runs more than that it is not pure air. That is, that it must be within six ten-thousandths of the outside atmosphere, and then it is to all intents and purposes pure. If it goes beyond that, it is questionable. Carbonic acid gas has been discussed considerably in Dr. Billings's book and elsewhere, and it is shown that the people who work in these bottling establishments, soda water establishments, where it exists in large quantities, are not at all unhealthy. It is simply as a general factor to indicate the general impurity of the air. Where that exists in large quantities, it is fair to presume that organic and other impurities exist in an equal proportion. That is the way I have always understood it.

Mr. Wadsworth: Taken in that sense, of course, it is perfectly correct. His statement, however, refers to carbonic acid itself, which he says is a poison, and the best of chemists I do not think would agree with him.

Mr. D. M. Quay: Mr. Kent asked a question about the advisability of taking out the air above the gas-light. I do not think the paper is quite as full on that question as it might be. We have found in practice that it is sometimes necessary to have openings above the floor. Where we do we always have a register. We do not leave them open. We find in certain buildings that it is necessary at times to take out part of the air at least higher than at the floor, but I do not think it wise to put in registered faces and leave them open, but have registers so that they can be controlled. The proper place to take out the air, except in exceptional cases, is near the floor.

LIV.

# HEATING A PRIVATE RESIDENCE WITH A WARM-AIR FURNACE.

BY B. HAROLD CARPENTER.

(Member of the Society.)

After all has been said and done regarding the heating of residences by various methods, is not the much abused warm-air furnace system, at least theoretically, the best adapted for residences of moderate size?

Acting on this line, we have endeavored to overcome some of the weak points common to this mode of heating.

*In the first place*, all the air to be warmed should be brought from outside of the building. To accomplish this, we have set the furnace over a pit built of brick and cement, which is connected to the outside of the building by a brick duct as straight as possible, avoiding angles, and of ample size to admit the air freely.

*In the second place*, gases and overheating the air should be avoided. To accomplish this a furnace was provided with as few joints as possible, these joints so constructed that they could be made practically airtight. To prevent overheating the air the furnace should have a large radiating surface.

*In the third place*, all the rooms should be heated evenly at all times, by concentrating and combining all the warm-air outlets.

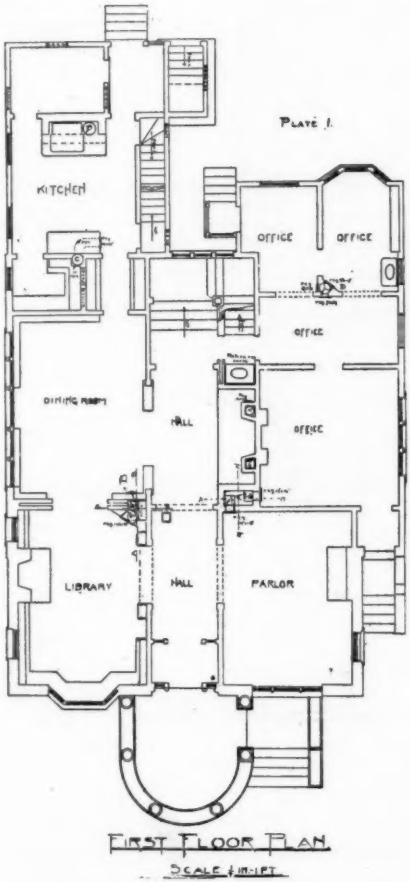
The furnace is the round, portable type, with base, fire pot and body of cast iron, body of dome and radiator of wrought iron or steel, top of dome and top and bottom of radiator of cast iron. All is encased in a double galvanized iron jacket. The grate being thirty inches in diameter, has a surface of 4.9 square feet.

The total radiating surface of fire pot, body, dome and radiator is 107 square feet, or a ratio between grate and radiating surface of 1 to 21.7.

The contents of the house heated is 38,800 cubical feet, which gives a ratio, between the radiating surface and the cubical contents of the house, of 1 to 365.

The grates used are of a triangular pattern and can be used with

pea coal, though for heavy firing in severe weather larger coal is more effective. A point frequently overlooked in the selection of a furnace and yet one of considerable importance is to have a reasonably deep ash pit, so that the ashes may be kept free from the grate with ease.

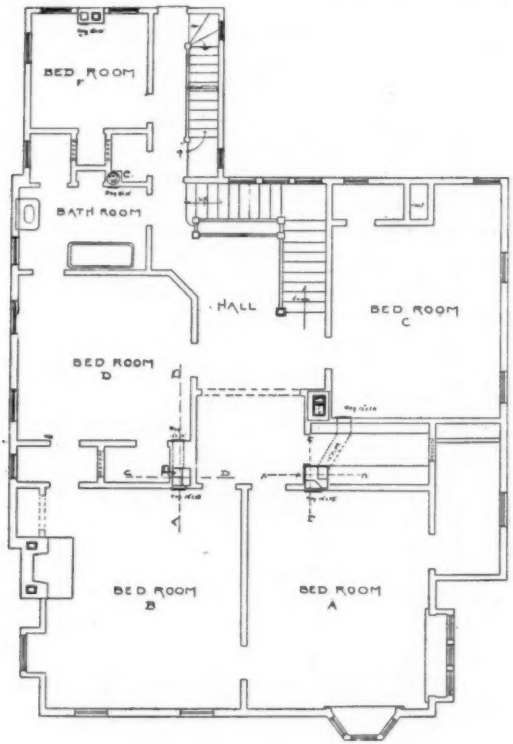



By referring to plate 7, Fig. i, we find the air passage between dome and radiator to be 8 inches, and the air passage between radiator and casing $4\frac{1}{2}$ inches; this gives a total of 12.5 square feet warmed flue space for the incoming air.

The bonnet on the furnace is 24 inches high above the radiator

or somewhat higher than usual. This is necessary so that the larger pipes can be taken off above the radiator.

Prof. Carpenter gives the velocity of air at this latitude to the first floor from 2.5 to 4 feet per second, to the second floor 5 feet per second, and to the third floor 6 feet per second.




PLATE·2.

SECOND FLOOR PLAN
SCALE ¼IN.-1FT.

This would give an average of 4.8 feet per second, or 288 feet per minute.

By multiplying the flue space by the speed we have 3,600 cubic feet of air per minute.

This being rightly distributed throughout the ducts and regis-

ters, would be sufficient (the contents of the house being 38,800 cubic feet) to change the air throughout the building every eleven minutes.

Plate 7, Fig. 2, shows partitions B B B B, which extend from top of bonnet to top of fire pot A A, shown in Fig. 1. These

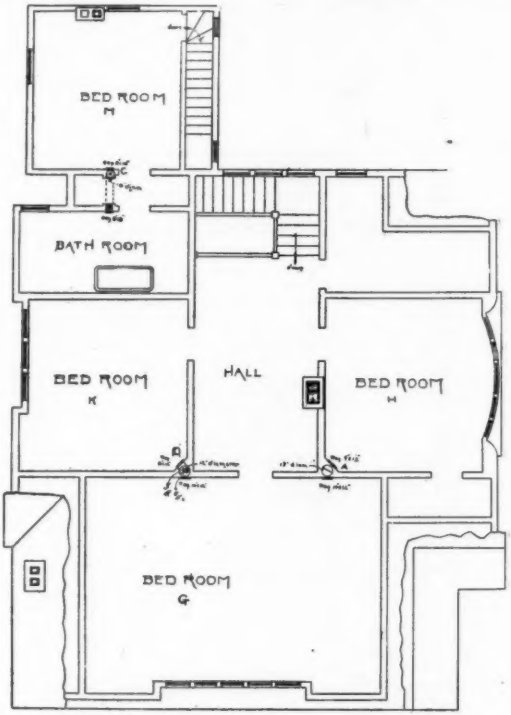



PLATE - 3

THIRD FLOOR PLAN.

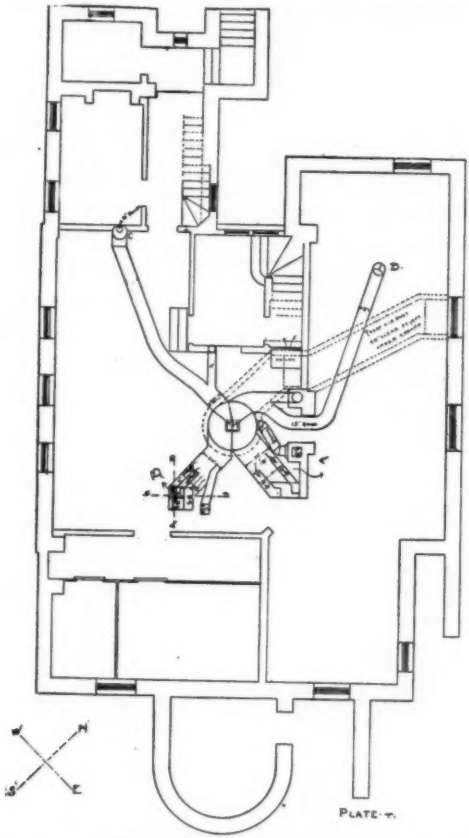
SCALE ¼ INCH - 1 FOOT.

partitions divide the space for incoming air into four unequal parts, and compel the air to pass into the proper distributing pipes.

Plate IV shows the furnace set over a brick pit which is connected to an opening on the north side of the building by a brick duct 12 square feet in area.

The furnace bonnet is connected to the rising pipes by galvanized ducts. There are but five rising pipes in the building, A, B, C, D and E. A is connected to six rooms, B to six rooms, C to four rooms, D to three rooms and E to one room.

Plate V gives a detail of riser A, with its various branches; it




BASEMENT PLAN.

also shows the valves V at foot of riser, which are placed to control the amount of air admitted to the various rooms. For a first-floor room a division is placed in the main duct, extending down to the elbow and about two feet into the horizontal duct in the basement where the valve V is placed. This is shown in plate 5, Fig. A. This

also shows the method of running risers to second floor. In all cases where branches are taken off of main riser, the branches or divisions extend into the main riser for from two to four feet. All elbows where possible are made round. All rising pipes are well covered with asbestos paper wired fast. We have endeavored to proportion the rising pipes so that each branch may get its proper proportion of air, the risers being reduced in size as each branch is taken from it. To obtain the proportion for size of pipe we use the following table:

**To find cubic feet of air passing through pipes to:**

1st floor, multiply area in inches by 1.25
2d floor, " " " 1.66
3d floor, " " " 2.08

| Diameter of warm air pipe. | Area of warm air pipe in inches. | Amount of air to first floor at a velocity of 3' per second, through different size pipes. | Amount of air to second floor at a velocity of 4' per second through different size pipes. | Amount of air to third floor at a velocity of 5' per second through different size pipes. |
|---|---|---|---|---|
| INCHES | INCHES | CU. FT. | CU. FT. | CU. FT. |
| 8 | 56 | 70 | 92 | 116 |
| 9 | 63 | 78 | 105 | 130 |
| 10 | 78 | 97 | 136 | 162 |
| 11 | 96 | 120 | 160 | 199 |
| 12 | 113 | 141 | 187 | 234 |
| 13 | 133 | 177 | 221 | 246 |
| 14 | 154 | 192 | 256 | 328 |
| 16 | 201 | 252 | 334 | 418 |
| 18 | 254 | 314 | 422 | 528 |
| 20 | 314 | 392 | 523 | 633 |
| 22 | 380 | 475 | 632 | 790 |
| 24 | 452 | 565 | 752 | 940 |
| 26 | 531 | 665 | 818 | 1104 |

The construction of the house made it necessary to use round risers in some places and in others square risers.

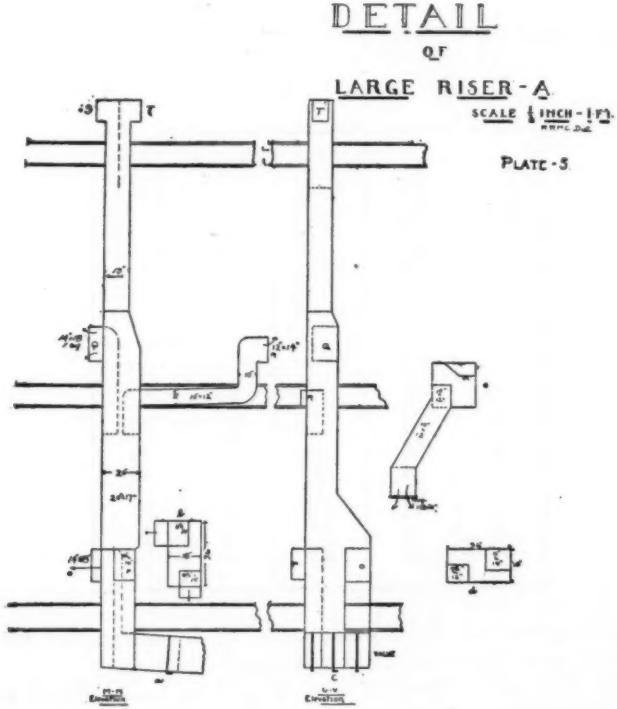
Plate VI gives a detail of riser B with its branches and connections which are similar to riser A. Plate VII gives a detail of riser C with fewer branches. We do not give a detail of riser D, as it is connected to the first floor only, being divided into three nearly equal parts.

Plate I shows a large return register under wash basin in rear hall. This is connected to the cold-air duct in the basement, and may be used at any time to warm the house quickly and economically by opening the return register and closing the valve

in cold-air box at the entrance to the basement. This allows the air in the rooms to return to the basement, where it is again warmed.

This feature is not particularly healthful, but compares favorably with a direct steam-heating system.

The owner expected to occupy this building by December 1, and we had hoped to make some tests to verify our figures, but in the latter part of November the building was so badly damaged by fire that we were unable to do so.



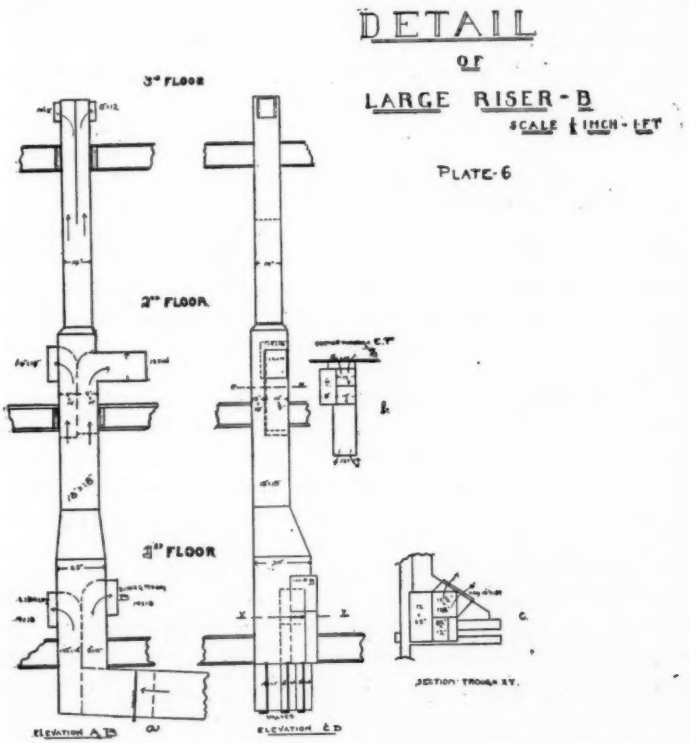

We know from experience that this arrangement of heaters, pipes, etc., is very satisfactory in operation and economical in fuel. The loss by radiation of exposed pipe surface in basement is reduced from ½ to 2-3.

The above arrangement has been used in a number of residences in our city, and by anemometer tests it shows that every room in the house gets its proportion of warmed air, pure and fresh.

DISCUSSION.

Mr. A. E. Kenrick: I would like to ask Mr. Carpenter if he prefers the wrought iron dome to the cast iron?

Mr. Carpenter: Well, we have found, generally speaking, that there is not much difference, as far as the construction of the furnace is concerned, unless there is a difference in the building or the base-




ment in which it is placed. If it is a damp basement, we use the cast iron. If it is not a damp place, it does not make very much difference. I have not found that there is a great deal of difference between the two.

Mr. Kenrick: Have you found any difference between the life of wrought iron and cast iron?

Mr. Carpenter: We have had cast iron furnaces, that were in use two or three years ago, that were placed there by my father thirty-

five years ago, and nothing has ever been changed in them except the grate, and they were giving yet good satisfaction.

Mr. Kenrick: Is it not a fact, that wrought iron deteriorates so that after five years' use you have to burn anywhere from a ton to a ton and a half more coal to get the same results?

Mr. Carpenter: The furnaces that we have used up until a few years ago have been almost entirely of the cast iron pattern. We have had less experience with the wrought iron than we have had with the cast. Our basements have been of a damp nature, and we have used cast iron more. Lately they are building drier cellars

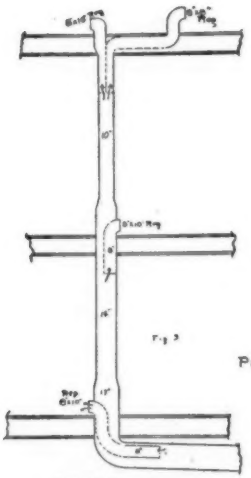
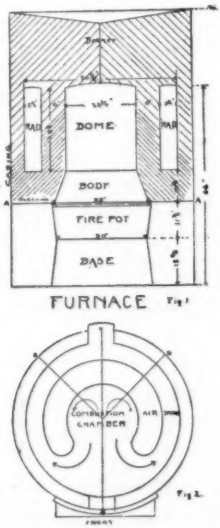



PLATE 7.




and concreting them more, and we have got more into the use of wrought iron, but we have always favored the cast iron.

Mr. Connolly: Mr. President, I would like to ask Mr. Carpenter if he uses double pipe for these risers in Wilkesbarre?

Mr. Carpenter. We have not in this case; it is all single.

Mr. Connolly: You also state that a fire occurred in the early part of November. Was it on account of the single pipes, or in connection with the hot air furnace?

Mr. Carpenter: I rather expected that question from either yourself or Mr. Barron.

Mr. Connolly: Well, I hope you will answer it.

Mr. Carpenter: It was not. It was, as near as they know, of incendiary origin, because it occurred in a closet where it was shut off from all light, so that you could not see it from the outside until it got a pretty good start. It was not from the warm air ducts.

Mr. Connolly: If a fire occurred within the limits of the Greater New York with that arrangement of piping, Mr. Barron or I might have to hustle around to get you out on bail, because it is really against the law to run single hot air pipes in wood partitions. There is another point that I would severely criticise in your interior cold air duct. You take a register and connect it with the cold air box, because, I presume, they are under a wash-basin. From a sanitary standpoint, I think it inefficient, dangerous, and not good practice.

Mr. Kent: A few questions I would like to ask on this paper. Mr. Eisert, in the last paper we had, gives a rule for the changing of air in rooms: "As a rule, rooms very little occupied require the air changed but once in one hour." Mr. Carpenter's plan changes the air once in eleven minutes, or five and a half times an hour. I would like to know why he wants the air changed so often as that in a private dwelling house? Again, I would like to know why he made the indraft cold air flue twelve square feet? It seems to me like a very large area for a private dwelling-house. I have in my house, which is not half the size of this one in the paper, a cold air flue. I am sure it is not over three or four square feet, and I have to cut it down to one-fifth of that in order to heat the house in cold weather.

The other thing is, about taking 3,600 cubic feet of air per minute into that house. I have made a calculation: Suppose you want to heat the air in that house, 3,600 cubic feet of air per minute, up to seventy degrees; not taking any account whatever of radiation or the loss due to leaks, but simply that you had to heat that amount of air, it would take nine hundred pounds of coal per hour. It would take at least as much more to heat the building without ventilating it, I suppose. I ask him if he has gone into any calculation as to the amount of heat that ought to be used for that house? I think the plan is all right. I think that he has been exceedingly liberal in his proportion of areas. What will happen will be, they will cut down that twelve square feet of area of cold air flue to say two square feet, and instead of burning nine hundred pounds of coal, they won't burn over one hundred; and instead of getting 3,600 cubic feet of air, they won't get over one-sixth of that. But the proportions are all right to give them as much more as they want.

Mr. Carpenter: I guess Mr. Kent is all right in that; but during moderate weather you need a large cold air box and large flues, in

order to get the proper amount of air. The difference between the air entering the building and the air in the building is small in proportion to that in the severe weather. In severe cold weather we would have to cut down this cold air box; there is no doubt of that, because the air entering at zero and warmed up to one hundred degrees, will pass so much more rapidly that you only need a small flue for it to go through. But in moderate weather, when the air is warm, thirty or forty degrees, or may be less, the air travels at such a sluggish rate that you need a large flue. We have proportioned these flues for moderate weather, as we have much more of that than we have of the extremely cold weather.

Referring to Mr. Connolly's criticism of taking the air under the wash-basin, if the wash-basin is so constructed that it will admit the foul air being taken down into the basement and brought back into the rooms, it certainly would admit the foul air right into the room itself where the basin is placed; so that should be done away with, anyway.

I should like to ask the President and the members to allow Mr. D. S. Richardson to address the meeting. He is not a member of our Society. I believe he may have some points that he can give us on this question.

The President: I am sure that the members will be glad to hear Mr. Richardson, whose experience in furnaces is probably more extended than that of any member of the Society. Gentlemen, I have the pleasure of introducing Mr. Richardson to you, if you do not already know him. He will kindly give us his opinion on Mr. Carpenter's paper.

Mr. D. S. Richardson: Mr. President, and Gentlemen:—

I did not expect to do any talking here to-night. I expected to come here to listen. But while there is a building law here in New York requiring double pipes, in an experience of over fifty years we have never known a house to be set on fire with single pipes properly put in. If that present plan is carried out in the City of New York, either one of two things has got to occur: All methods of heating by either hot air furnace or by indirect radiation have got to be a thing of the past. It is either direct radiation or indirect, as you cannot get up double pipes through each partition and get any size to them, to get capacity of air through them.

Now, regarding the size of the cold air box to a furnace: The average furnace in an ordinary house has six or eight air pipes. The average way that people run furnaces or try to run them, or try to heat the house, if they have a cold air box of sufficient size to

heat that house or to fill those pipes, is this: The average servant will shut the cold air box about three-quarters or seven-eighths of the way. The result is, that the cold rooms or the rooms on the cold side of the house, instead of having any heat going through those pipes, are supplying the air chamber with cold air. The air is going down the registers of those rooms. The method that Mr. Carpenter has given us to-night I consider a very good one, and it has many decided advantages over other constructions. We find that in all exposed houses it is always best to have an air settling chamber, or an air room, bringing the cold air box from the outside into the top of this room, and taking the cold air from the bottom of the room into the furnace. There has been nothing said about the depth of the pit under the furnace, but I have seen a number of furnaces put up apparently all right, well located, well piped, good elevations, but the air didn't seem to go through the pipes with any degree of force. In every such case, I have always found that if all other conditions were right, that that pit would be anywhere from eighteen inches to two feet deep. By simply filling up that pit so that it is not over fourteen inches in depth, the air will go through that furnace perfectly and fill all the pipes finely; whereas, with the deep pit it would not flow. Why it is so, I don't know. I never have been able to find anybody to tell me.

Regarding Mr. Kenrick's question about experience with wrought iron and cast iron for radiators, I have seen sheet iron radiators put in over thirty years ago, in good condition, after thirty years' use. So far as the radiating quality is concerned, I don't think there is any difference between cast iron and wrought iron, of the same thickness. A wrought iron radiator because it is thinner radiates heat much more rapidly than a thick cast iron radiator. It also cools off more rapidly. The only objection to an all cast iron furnace is the time it takes to get heated up in the morning. Possibly you will be interested to know of an experiment: I have been trying to get some information, but I have not as yet been able to find the first particle of information that is of practical value. A year ago last fall I set up a portable furnace in a room 90 by 100, carried six 8-inch pipes off from this furnace on a dead level. The longest pipe was 60 feet, and the next 50, 40, 30, 20 and 10. I then burned a fire in the furnace and found that I could get a moderate amount of heat in about three of the pipes, but the others I could not get any heat from; didn't expect to. The ends of all those pipes were just five feet from the floor, and on a dead level. By putting an ordinary buzzer, so-called, an electric fan in front of the opening of the fur-

nace—the cold air box—I found that I could get a good current of air in all those pipes; so much so, that I had to have dampers. In fact, I put the dampers in to begin with, in all these pipes, but the force of the air against the ash-pit sent the air out again on each corner. I then took a cold air box about eight feet long, took the air right into this main room, and with the fan running, sixteen inches in diameter—and it takes about as much power to run it as it does two of those sixteen candle power lights—I found that I could get a current of air through all those pipes, so that it would hold a handkerchief right out straight. I had to close my dampers in all of the three shorter pipes part way. The ten-foot pipe was more than half way closed, and the longer pipes were graded, so as to get an equal amount of air in all those pipes. I took ten feet off the fifty-foot pipe, turned an angle on it and found it didn't make any difference in the current of air. I then turned another angle and brought it back to the furnace about ten feet. That made a little difference, but not much. Now, the time has come when a warm air furnace put into a house with an ordinary fan, noiseless with the pressure—I don't think it is going to require more than a quarter of an ounce pressure, if it does that, to send warm air through all your system of piping, and I believe it is just as easy to heat a room sixty feet away from your furnace as one ten feet away from your furnace. I have had considerable experience with steam and with hot water heating as well, and I have yet to find anything that compares with either a good warm air furnace or an indirect heating system of steam, but with the indirect heating system you get the same temperature this kind of weather as you do if your thermometer is at zero, and you are burning a great deal more fuel than you do in a furnace. What I have been trying to find was, first, a motor where they have no electricity, where they could be put in to run this fan. That is the coming thing for heating. Some five or six years ago there was a concern from Boston came to Brooklyn and put in a steam apparatus and the indirect radiation, and put a little fan in the cold air box. Much to my surprise, they used four-inch hot air pipes, where we would use eight or nine. The largest hot air pipe they had was a six-inch pipe, where we would use the twelve. They took the cold air in with a Davidson fan, I think it was. However, with these little four-inch pipes coming out of the tops of the chamber, they have heated that house for five years, and given excellent satisfaction. They use the same plan for ventilating the house in the summer as they do in the winter. With the fan it does not require anything like as much pipe as is required on the

gravity system. I think possibly one-third the size would be sufficient, and the only objection to it is, that if your fan is out of order, or your electricity gives out, you cannot heat your house: whereas, if you have the regular size pipes and have your dampers in, in case your electricity gives out you simply open your dampers and three-quarters of the house is heated.

Mr. Kenrick: I would like to ask Mr. Richardson in that experiment from what quarter his cold air box came, and in what direction the hot air pipes were run?

Mr. Richards: The air pipe was running in either direction from the furnace.

Mr. Kenrick: In regard to the question of wrought iron, in 1875 there was a great craze over in our territory in regard to people being killed with cast iron furnaces, and everybody put in wrought iron. Now they all have discarded them. It has been proven that the wrought iron furnace will deteriorate after five years' constant use, so that it requires more coal the sixth or seventh year than it ever took before. A wrought iron furnace will leak gas quicker than a cast iron.

Mr. Richardson: The reason that these wrought iron furnaces gave out as they did was that you would always find a hole burned right through the top of them. The reason was that they did not guide the air to the surface; it was too hot. Unless you brought the air over that surface, it would just simply melt right down. So far as the theory at that time was concerned, it was a money-making device of Dr. Nicholls; there was nothing in it, and that was a bubble that was exploded, as you say, some ten or fifteen years ago.

Mr. Quay: In the first part of Mr. Carpenter's paper, he states that all the air to be warmed should be brought from the outside of the building. I find further on, however, that he modifies that a little. I do not think it is necessary in houses of this size to bring the air from the outside at all times. I think it is necessary to have an outside cold air duct, but have found that you can take the air from the front hall near the outside door part of the time, in heating a house that hasn't many occupants, very safely.

Another question, in regard to taking the air from the north side of a house: If there are any hot air pipes of considerable length leading to the south part of the house, and you have a wind of high velocity from the south, what effect would it have if the cold air duct was taken from the north side only, especially in heating south rooms?

Mr. Carpenter: When we have a south wind, it is a warm wind.

I have found from our experience, though, that all the troubles that we have ever had in heating is with southwest rooms, although the south winds are the warm winds. I think, probably, that there are two reasons for that: One is, that we protect the north and northwest and west rooms more than we do the south and southwest, and then if we do have a heavy southwest wind, we are not prepared for it. In many cases, we take a cold air box from both sides of the building. Where we can we prefer to. But in some cases, it is not practicable, and we have to take it all from one side, and then, if possible, not have any of the pipes running a long way from the furnace. I would like to hear from some one that has had experience in the manner in which the pipes have been run.

Mr. Connolly: I would like to ask Mr. Carpenter if he has found better results from taking one large pipe out with its branches, or with individual pipes?

Mr. Carpenter: Yes; we have, and we have found better results.

Mr. Connolly: I rather like the idea.

Mr. Carpenter: We found better results, and there is considerably less friction surely. There is less radiating surface in the basement.

Mr. Connolly: I would like to know from Mr. Richardson if that is the usual practice now, in hot air heating, taking out the branches the same as you would in direct steam work, with a cold air box?

Mr. Richardson: Pipes in city houses have been used for years as they go up in height, but there are very few houses that have had this system put in; that is, in this section.

Mr. Connolly: Do you use evaporating pans, Mr. Carpenter?

Mr. Carpenter: No; we haven't used the water pan for some time. Where you put in a large cold air box and large flues, you don't have to heat the air up several hundred degrees to get it to the point you wish it. The air is pure; you do not burn the moisture out of it. Our idea has been to warm the air and give large volumes of it rather than to bake it and give small volumes. If you do this, then you want a water-pan—something to give back this moisture. I started out here in saying that I thought the furnace system was about the best system, and while we do heating of the various kinds, the furnace system, rightly put in, gives excellent satisfaction. Although the majority of this body are probably steam men, I think that when people come back to their sober senses, they will come back to furnaces for the great majority of our smaller houses.

Mr. Connolly: When they do, I think you will be growing honeysuckles on Mont Blanc.

Mr. Kenrick: I commenced in the hot air heating business in about 1866. I have probably erected during my time somewhere in the neighborhood of fifteen hundred hot air furnaces, and I have had all sorts of experience with them. Mr. Richardson speaks of the cold air box. I have been called into houses where there was trouble. I would find that the hot air pipes would have somewhere from five to six hundred square inches, and the cold air box would have a capacity of from seventy-five to one hundred. In that case, you would find that the hot air was all confined in the gases in the furnace and lying there stagnant. There was nothing to push it along and send it upstairs. Mr. Carpenter's arrangement for his upright risers we can thoroughly agree with, but it is almost the universal practice—in answer to Mr. Connolly—that each room is separate, by itself. That is our practice in the East, and has been for years.

Mr. Carpenter: We were called in, in the fall, to solve a problem. The owners said the furnace would not heat; they had had five furnace men to examine it and could not find where the trouble was, and after a few moments looking about, we found that the flagstone covering over the cold air box had openings in it large enough to admit sufficient ashes to completely fill the cold air box.

There was no air going through it at all, yet there were five men who professed to know their business, who were called in to examine it and could not tell where the trouble was.

Mr. Gormly: One important point in this matter appears to have escaped notice. It would be a violation of well known sanitary laws to place a brick cold air duct under ground without taking special means to exclude ground air. It is a well known fact that many buildings are erected upon earth which is saturated with decaying animal and vegetable matter, notably in low swampy ground which has been filled to grade with the refuse matter of a city. Such matter generates a gas injurious to human beings. Bricks as ordinarily made and laid are not gas tight. In fact, they are not water tight. The interior of a fresh air duct could readily become contaminated by sewer gas and sewage if a drain in the vicinity of a fresh air duct should become defective. I have frequently seen sewage flowing into fresh air ducts through the bricks of the duct. A brick duct, well laid on a good foundation, not liable to settle and crack, and totally surrounded with a good cement grouting, might in certain places be reasonably safe. But where the duct can as well be laid above grade I would consider it a much more sanitary arrangement to so locate it.

Mr. Kenrick: Up to some twenty-five years ago it was the universal practice—I think Mr. Richardson will bear me out—to take in the cold air at the top of the furnace and bring it down around the sides and through pigeon-holes at the bottom, to supply the air to the furnace. But the difficulty was that the incoming air would chill the hot air pipes where they passed through that chamber, and prevent circulation.

The President: I do not think you understand Mr. Gormly properly. Mr. Gormly's idea is, that it is bad practice for a fresh air inlet to run under ground, and I think what he means is to bring it across the ceiling and drop it to the base of the heating chamber.

Mr. Gormly: That is the idea.

The President: And that, I believe, is understood by good engineers to be good practice. He must drop it to the bottom of the furnace. The idea you spoke of was tried by McGee a number of years ago.

Mr. Kenrick: It was tried by Bryant and Manning.

Mr. Connolly: I would say here that I am not criticising hot air furnaces. I have had experience with the three systems of heating, and I have known of hot air furnaces which have been put in and have given good results, and I think now that the hot air furnace, where considerable thought is given to it, where it is properly set, is really better than a direct steam job in some cases. In regard to the question of economy, I do not agree with Mr. Richardson at all. Take Riverside Drive from a real estate standpoint and from a heating engineer's standpoint, and it is one of the coldest locations in New York. After heating forty houses there in the last five years, and from my general knowledge and experience of hot air furnace heating, I do not think that hot air furnaces will answer on Riverside Drive at all.

About the cold air box: I have known a case in South Manchester, Connecticut, where a hot air furnace is in and the cold air box run under ground to a small elevation, to a cluster of pine trees, some five or six hundred feet away, and the air that comes through that duct is simply perfection. Of course, it is air-tight and waterproof.

The President: Well, that is an instance of the exception proving the rule.

Mr. Quay: In regard to Mr. Gormly's criticism in respect to running ducts under ground for hot air heating or any other pipes, I think they shouldn't be run under ground except where you cannot run them any other place, and if you do run them under ground

they should be made not only air-tight, but absolutely water-tight.

The President: I think there is only one other question of Mr. Kent's that remains unanswered, and that is the question between Mr. Eisert's paper and Mr. Carpenter's tabulation of air supply. As I understood the paper of Mr. Eisert, he simply stated the amount of air that was necessary to be supplied to each living room in a house. Now, it might be that it is heated by direct steam or something of that kind, and a small amount of direct or indirect or semi-direct radiation would give that amount of air. In Mr. Carpenter's method, warm air furnace, of course, that is heating by the transmission of the heated air and not by radiation, and he carries his heat units in, for the purpose of returning it. There is no objection to so much more air, even if only so much is really necessary. That might account for the discrepancy as to what is really required and the excess which is provided by the warm air furnace method.

Mr. Kent: I would like to ask Mr. Carpenter in regard to heating that vast amount—3,600 cubic feet per minute—whether he would not in practice take the largest amount of that air from the hall, and not from out-of-doors in cold weather, to save fuel?

Mr. Carpenter: It no doubt would save fuel, but in severe cold weather they will either have to do that or cut off part of the cold air box. If the heater was large enough, it would take a much larger amount of air in the house than was at all necessary. Mr. Connolly spoke of the size of the heater. The size of the heater is all right for the amount of work. In zero weather, with a cold air box of twelve square feet in area, and heat the air up to a hundred or 110 or 120 degrees, it would pass through so lively that the furnace would not be able to heat it; but for the purpose of heating that house and giving a good ventilation the furnace is ample to do the work.

Mr. Connolly: How about rating the furnace on cubical contents?

Mr. Carpenter: This proportion is probably a half larger than the Professor gives for it; but you must bear in mind that the residence is not all used at the same time. While it will heat the whole house, it is like all other houses partially used, and it is ample to do the work for that residence, and the square feet of radiation in the heaters is ample for the work. His sizes are all right. If you are going to heat the house in zero weather to seventy degrees and give it about the same amount of air that we are giving here in moderate weather, all right; but it is not necessary.

Mr. Barwick: In reference to these warm air furnaces, Mr.

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Carpenter has gone so far as to give a design of a device that on the face of it looks very good, and no doubt the air supply he there assumes will be ample. But he has not gone far enough. He should have given us the amount of wall surface, the amount of glass surface, the absolute cubic contents of the house, so that we would have something to base our calculations on, as to whether the plant that is proposed is ample to do the work. It would also have been better if he could have got at the effect after running the plant. He states in his paper that the building was so badly damaged by fire that it was impossible to get a test from this apparatus. The heating of the house by furnace no doubt can be accomplished, provided they can keep the furnace joints tight, so as to prevent gases from leaking into the air. But this is really of no value to the Society, as far as it goes, unless we have some more data by which we could follow it up more closely.

The President: This paper is not in respect to the advantages of the furnace *versus* the steam plant. It is simply the experience of Mr. Carpenter regarding the warming of a building with a warm air furnace, not its relative radiating surface as against cubical contents and the glass surfaces, &c. It is simply a paper of his experience. I do not think that Mr. Carpenter should be criticised for not going into that detail. I will say, for Mr. Richardson's information, a memorandum has been handed to me that in Chicago two or three years ago Mr. George Hoffman made experiments with a fan similar to those referred to, and used for motive power a small water mill. I would like to ask Mr. Richardson if it is not the common practice, basing the outside temperature at 32, to make your fresh air inlet eighty per cent of the total area of your warm air pipes, so that by expansion you get the full air supply, and keeping to that area you get it right?

Mr. Richardson: That is a little larger percentage than has been given heretofore, but I think is nearer correct. Eighty per cent is a little larger size of cold aid box in proportion to the capacity of the pipes than has been used generally. It has been found that with a cold air box even the full size of the capacity of all the hot air pipes we get better results. There is another peculiar feature, as regards the flow of air through an air box: In Canada, in Northern Vermont, and in parts of Maine and New Hampshire, a cold air box does not work with the thermometer at zero or five below. It is absolutely impossible to get any air through the cold air box; whether it is because it is so rarely rarefied there or not, I don't know, but in Canada houses are built with double windows.

and they take the air when the thermometer gets anywhere near zero from the main body of the house; they have to do it. They could not get the air to flow through the cold air box. We could never have any trouble of that kind in this section or in countries where there is so much humidity in the air.

Mr. Kent: I think I can explain that occurrence in Canada. When the thermometer gets down low there every crevice in the house is shut up, so that there is no way for the air to circulate and get out of the house.

Mr. Richardson: They have open fire-places.

Mr. Kent: I thought they shut them up at such times and shut all the dampers, to prevent drafts. If you open the fire-place you get a circulation.

Mr. Jellett: Referring to Mr. Kent's question as to the change of air, I do not think the reason was given very clearly on that point. Mr. Eisert has written a paper on the necessity of ventilation. He says nothing about heating a building; but that in an ordinary building, to keep down the percentage of vitiation, one change every hour is sufficient. One change per hour—take a room 15 by 20, ten feet high, 3,000 cubic feet of air—to attempt to put 3,000 cubic feet of air into that room—you might get all the air necessary for ventilation, but you would never warm it to 70. You have to have at least four changes of air per hour on the cold side of the house to maintain the temperature. You do not need that air for ventilation, but you do for heating. You would not need so many changes for direct radiation. I think there has been some confusion in this discussion as to what is necessary for ventilation and what is necessary for heating. They are entirely different things from this point of view.

Mr. Meyer: May I ask Mr. Carpenter if he has had any experience with the use of thermostats for controlling furnaces, and if they were successful or not?

Mr. Carpenter: I have had some, yes. Do you mean in residence work or in school work? We have used thermostats in both cases. Of course, in a residence you will have to put your thermostat in the hall or in some part of the building open to all the rooms. One thermostat cannot control all the rooms; that is impossible, but you can control the room in which it is set. I think a part of the bad work done with the furnaces is because they do not receive the attention they should. On a steam boiler there is a diaphragm which regulates the temperature. With a furnace, the servant takes care of it, probably, and he or she will throw on coal and turn on the

damper, and expect in half an hour to go down and change them. They let them go until everything is burned up, and they don't take care of them. If it has an automatic apparatus of some kind to take care of it, it is a very big benefit to the furnace.

Mr. Jellett: There are some things I know a good deal more about than hot air furnaces. My first experience with hot air furnaces was in my own house. When I first took the house, it had a furnace which I was told was ample to warm it. That was about the first of November. Towards the end of November, when the temperature got to about 34, I found that the best temperature I could get in the house was 56; this was not satisfactory to me. It might have been to the previous occupant. I then took an interest in the furnace which I had not taken before. I examined it very carefully —found the size of the grate and the amount of surface to it. Then I noticed that there were three pipes from the furnace, and only three pipes. I followed those flues, and I found that one which was 4 by 12 inches supplied the library, which was a room about 12 by 15 feet, and has an eleven foot ceiling and four windows in it. It supplied a hall which is five feet wide and probably thirty long, and runs through three stories of the house—a long, narrow house. That same flue then passed upstairs and took a small back bed-room, a room about 10 by 12, with a nine foot ceiling. It was presumed to warm all three. The second flue opened into a 9 by 9 chimney, that discharged into the parlor, which is 27 feet by about 12 and has four windows in it. It then passed to the second story front room, which is fifteen feet square, with a nine foot ceiling and three windows; then to the third story to a room of similar size with a lower ceiling. The third flue was supposed to warm the bath-room and the sitting-room in the rear. I took that same furnace and cut into the top of it four more pipes. I cut off all the old flues that discharged to the first floor, tore the dampers out of them; let the heat go upstairs; took the four new pipes that I put in, run one to the first floor hall, one into the corner of the parlor, one directly into the library, and one which took the back room. The largest of these pipes was twelve inches; the others were ten inches in diameter. The furnace man who made the furnace said that it was simply ridiculous to put that many pipes on that little furnace. I said, "I think your furnace is choking for want of air; I think that is all that is the matter with it; I am burning enough coal to heat three times the volume of air that can possibly pass through those pipes at that velocity." I passed the rest of the winter in that house very comfortably. I gave it a larger cold air supply. I think that

certainly half the hot air furnaces that I have paid any attention to have failed for want of sufficient air and the necessary area of flues to carry the air they could heat to the rooms.

The President: You had better make that three-quarters!

Mr. Jellett: All right, I will go as far as that. The same winter a friend who lived near me came to me and said he could not heat his house. He said, "I have a new furnace in, and the house is like a barn to-night." I went to his house, and found that he had new pipes—everything all right—a large furnace. I said, "Where is your air box?" He said, "We take air from the cellar." "Where does your cellar get the air from," I asked. He looked at me in amazement. I said, "I have noticed that you have carefully weather-stripped all these windows—your cellar door is stripped, to prevent air coming in. Where does your cellar get its air from?" He said, "I never thought of that." He said, "I don't think that would have this effect." I said, "For experiment, let us open one of your cellar windows." He opened the cellar window, and the house was heated inside of thirty or forty minutes. He was an intelligent man, a manufacturer in other lines, but it never occurred to him that the thing had to have something to breathe with. I think that is the case very often.

IV.

# SOME POINTS REGARDING THE VENTILATION AND HEATING OF TALL BUILDINGS.

BY HENRY C. MEYER, JR.
(Member of the Society.)

In the hope that it would lead to a discussion of interest, the following somewhat disconnected remarks concerning the ventilation of tall buildings, and some of the details of their steam heating plant, are presented by the author, whose work has made it necessary to study carefully the details of the mechanical plants of our tall buildings since their development began some ten years ago.

The demand for proper ventilation in the modern office buildings is of recent origin and it is very seldom, even now, that means are provided for furnishing a supply of pure air. This demand is not so great as it ought to be, nor is it so great as it would be if architects and engineers were to urge upon building owners that the same means be provided for encouraging a healthier condition of mind and body in our businesss men and women, who spend almost the entire daytime in their offices, that these business men demand in the way of proper ventilation for the schoolrooms in which their children spend a portion of their time. Some men object very strongly to their children being exposed to anything but the best sanitary conditions, yet themselves spend their daytime in an atmosphere which is anything but healthful. The author has visited many offices in our most recent buildings which, when entered from the outer air, appeared to possess at least some of the properties found in the air of menageries, and when one of these properties, that affecting the sense of smell, is apparent, it is a pretty sure sign that ventilation is needed. Perhaps some day business men will wake up to the fact that their work can be done more easily if their offices are furnished with a pure air supply, and will demand it. The increased cost of a ventilating system over the ordinary heating job would make such a slight addition to the cost of a large building that it would seem good engineering on the

part of the architect to provide for it, and a good business investment on the part of the owners to pay for it. Of course, the cost of operating the ventilating system is greater than the cost of heating alone, but the increased cost would have such a slight effect upon rental values that the installation of a ventilating plant certainly ought to attract rather than keep away tenants. In considering the cost of a ventilating system it should not be forgotten that the number of really cold days in a year in the latitude of New York and Chicago is not very great, and also that in almost all the tall buildings there is considerably more exhaust steam than is needed to do the simple heating of the building.

One of the earliest really tall buildings in which provision was made for an air supply was the Manhattan Life Building in New York city. In this the building is warmed by direct radiators placed inside of the windows. Long narrow slots were cut in the window sills admitting fresh air over the radiators, so that it would meet and mingle with the column of heated air rising from the radiators. To make the air supply independent of the force and direction of the wind, each room is connected to one of four systems of foul-air ducts carried above a suspended ceiling in the corridors, each of the ducts connecting with a flue or shaft leading to a fan chamber on the roof where a powerful exhaust fan tends to create a vacuum throughout the building, which insures a flow of fresh air through the window openings. Messrs. Kimball & Thompson were the architects of this building, and Messrs. Gillis & Geoghegan the heating contractors.

A novel ventilating plant for a tall building is to be found in the 11-story Real Estate Exchange, in Buffalo, where a blower system is relied upon entirely for heat and ventilation, there being no direct radiation in the building. Two independent hot-blast coils and fans are employed. The building is E shaped in plan. Near each angle in the building is a shaft running from the cellar to the upper floors and containing a number of galvanized iron flues, one independent flue being carried up from the coils to each of the upper floors. Each flue supplies one-half of a floor, and does this by means of a duct located above a suspended ceiling, the duct supplying registers opening into the top of each room. The air passes out of the rooms through registers into the corridor and leaves the building through openings over the elevator shaft. The architects of the building, Messrs. Green & Wicks, of Buffalo, informed the author but a few weeks ago that the plant cost but little more than the ordinary heating system and had given ex-

cellent satisfaction, so much so that they would install the same system again if opportunity offered. The Buffalo Forge Company were the contractors for the heating system. In this building the temperature of the rooms is regulated by controlling the amount of heated air admitted, as all of the air must be raised to a temperature necessary to warm the most exposed rooms. The ideal arrangement would be to have a double-duct system, that is, a hot and cold air duct, with a mixing damper for each room, but the cost of such a plant would make it almost out of the question. It might be well, therefore, in such a system of air supply, to depend partly on direct radiators, say to put in enough to supply the heat transmitted by the walls and windows, and depend upon the blower system for air for ventilation only.

Still another type of ventilating apparatus is found in the American Surety Building, in New York city, of which Mr. Bruce Price was the architect. Mr. Alfred R. Wolff, who designed the ventilating system, provided an extensive Sturtevant hot-blast plant in the basement supplying about four changes of air per hour to the seven lower stories. From each of these, foul air was drawn by flues to fan chambers on the roof. The plant of the Singer Building, in New York, and that of the Carnegie Building, in Pittsburg, both designed by Mr. Wolff, are arranged with the direct-indirect system of supply with an exhaust ventilating system, and both are said to have been very satisfactory. In all probability this last-mentioned type of plant or that used in the Buffalo building mentioned will be most used in the future, as the flues required in the system where the air is both supplied and removed by a blower system takes up so much room as to render them objectionable, particularly if the building is a tall one.

The author believes that there is room for improvement in some of the details of the steam and exhaust piping in our modern buildings. Too frequently has it been the custom in connecting engines and boilers to run a main from the boilers to the engines, with branches leading from the side and occasionally from the end of these mains to the engines. The danger from water finding its way into the engine cylinders and wrecking them has been shown sufficiently often to demonstrate the danger in a plant so designed. The author believes that in office buildings where the head room is restricted, a good arrangement is to provide an elbow on the nozzle of each boiler and run a horizontal pipe from the elbow to an angle stop-valve bolted to a flanged nozzle on top of the steam main. The stop-valve should have its stem in a vertical position, so that, on shutting down

the boiler, there is no pressure on the packing when it is required to repack the valve. The branches to the engines should in every instance be taken from the top of the main. Not long ago the author was shown a plant where this was not done, and the statement was made that the designer wished to connect the branches to the top of the main, but did not do so on account of the lack of head room. This difficulty might have been overcome, however, by lowering the steam pipe. The connections to steam pumps which have a variable stroke will not, of course, be damaged by water, hence it does no harm to connect the steam supply pipes for pumps to the side of the mains. The author was shown one plant where the connections to the pump were made at the bottom of a steam main, the object being to drain the main in this way. This, however, does not seem to be good practice, as it tends to turn a steam cylinder into a pump; moreover, the condensation in the steam main contains no oil and is at high temperature, and, therefore, could well be returned directly to the boilers.

This raises the question of the disposition of drips, which is an interesting one. The high-pressure drip—that is, the condensation which occurs in the high-pressure steam pipes—can be led to a trap or traps if the different drains are likely to be under different pressures. The traps can either discharge into the main return tank, from which the condensation may be pumped back to the boilers by a regular boiler feed pump; or they can discharge into an automatic receiver and pump, the latter returning it to the boilers. In large plants, where the condensation in high-pressure pipes is considerable, the latter method is sometimes adopted. The author is of the belief that engineers have, in many instances, gone too far in endeavoring to save the heat of steam condensed in exhaust pipes, feed-water heaters, etc. The reason for this belief is that almost all of our large buildings—every one in New York city except perhaps the Bowling Green Building—have more steam exhausted by the engines and pumps than they can possibly condense in their heating systems, and for that reason it is best to let the low-pressure drips go to waste than attempt to save the heat they contain, as the heat necesssary to warm the cold feed which would have to be supplied to take the place of the drip wasted could be warmed in the feed-water heater by a part of the steam which would otherwise pass into the atmosphere. Of course, if the cost of water should warrant such an action, or if the feed-water should be such as to cause scale to form in the boilers, it might be better to save the drip from the low-pressure piping and in the feed-water heater if it is of the closed type;

rendering it harmless by the use of some form of mechanical filter for removing the oil. Unless a filter is used the author is strongly in favor of throwing away the drip from all exhaust piping and the condensation that occurs in a closed feed-water heater.

The location of the grease separator is an important point, yet it is one that occasionally some one does not seem to appreciate. The separator should be so located as to protect the heating system and also the feed-water heater, no matter whether it be of the open or closed type; with the former to keep the grease from coming in contact with the feed-water, and with the latter to keep the grease from collecting on the tubes of the heater and impairing its efficiency.

A suggestion was made to the author several years ago by Mr. W. J. Baldwin which seems to him to deserve wide publicity. The ordinary exhaust-steam heating system usually consists of a main exhaust pipe dividing into two pipes, one containing a back-pressure valve and leading to the atmosphere, while the other conveys the exhaust steam to the heating system. As is usual, a reducing valve admits steam to this latter pipe to supplement the supply of exhaust steam when necessary, and it was found in a certain plant that occasionally, owing perhaps to lack of proper adjustment, the reducing valve would open when the pressure in the heating system was high enough to open the back-pressure valve so that live steam was blowing through the back-pressure valve and out in the atmosphere. This was discovered and the evil remedied by placing a check valve in the branch leading to the heating system, so that live steam could not flow through the reducing valve and out into the atmospheric connection. It occurred to the author that as back-pressure valves are usually set to open at a pressure of from two to three pounds on the heating system, and reducing valves to open at some lower pressure, there is not much margin, so that many plants may occasionally suffer a loss of steam from the cause mentioned. A balanced check valve designed to offer little resistance to the passage of steam flowing through it in the proper direction would overcome this.

DISCUSSION.

Mr. Paul: There is one point in this paper that I would like to refer to. I think you will find many plants which are throwing live steam to the atmosphere. That is my experience. You will find that in quite a number of cases.

Mr. Webster: We have had considerable experience in that line. We found a number of cases where live steam was being wasted on account of the pressure-reducing valve not being properly adjusted.

We haven't found many cases, however, where it was necessary not to save the condensation from the heating apparatus.

Prof. Carpenter: I wish to compliment the author of this paper on the admirable statement that he has made in relation to the various systems in use in heating tall buildings. It seems to me it is admirable, and it is perfectly fair to all the systems which are in use. There is in the paper a very great amount of information to me, for the reason that I have had almost no experience with that kind of work.

Mr. Jellett: There is one statement in here about the blower system in office buildings using hot and tempered air ducts, controlled by regulating devices. There has recently been a building completed in Philadelphia in which this system is in use. The tenants are coming into it now. I do not believe at present there is more than one-third of it occupied, so it is too early to speak of results. They use a false base in the ceiling of the corridors. I had nothing to do with it, but am interested in watching the results. The building is very much exposed, and if the results promised are obtained it is going to be a very satisfactory system. They have dropped the ceilings in the corridors and bring the air ducts up through main vertical shafts, delivering in the same manner as described in this building in Buffalo, but they bring a tempered air duct side by side with the hot-air duct and control the branches by a swinging damper back of the register in each room controlled by the thermostat, and the thermostat is, of course, controlled by the thermometer in the principal office. They then ventilate the room by a register set into the partition wall next to the corridor, which drops and offsets so that there will be no direct communication between the corridor and the room. The discharge is into the corridors, and the exhaust from the corridors is into the elevator shaft, which is ventilated above, and into the direct rooms, which have swinging transoms. On the opposite side of the toilet room is an aspirating flue. It acts very well so far as ventilating the toilet room is concerned, but there is a decided objection to it, I find, from the fact that the noise of the flush tanks, etc., is distinctly audible through the corridors, and I think that will kill its use on the ground that it is disagreeable; but there is no reason why some other method of relieving the pressure in the corridor should not be applied. I notice that there is an unusual amount of draft in the corridors, due to this arrangement. If the air was drawn out at two or three points instead of one point that would not be noticed. I asked the architect of the building about it, and he said that so far the only

complaint that he has had to make about it is that it has been too much heated; that they set the thermostats too high. The adjustment is now going on through the building, as the different rooms are occupied. That is taking the Buffalo Real Estate Exchange plan and carrying it considerably further and making individual regulation for the various rooms. As soon as the entire work is completed I can get the information as to the cost of the plant and the proportion of space, and then we will know what the amount is in proportion to other methods of heating such a building. I doubt very much, outside of the cost of the thermostats, if the expense in that particular building was any greater than the average system. Of course, the thermostat added to it would increase it.

Mr. Paul: I have found by experience that balanced check valves, or valves as nearly balanced as we find them, easily get out of order, or the pressure on the plant changes, with the result that live steam alone is utilized for the heating, all of the exhaust being wasted. The only plan I have found positive and reliable is to have a recording gauge and hold those in charge to maintain a fixed pressure in operating the heating. In this way you can get a reliable and economical plant.

I will state for te benefit of the society that the American Tract Building is heated by exhaust (except on the very coldest days) without back pressure. In the new Park Row Building the loss of pressure in delivering steam from the basement up thirty-two stories is, I am just informed, one and one-half inches. This is under working conditions.

Prof. Carpenter: What is that pressure?

Mr. Paul: Atmosphere at basement and inch and a half at the top of the riser at the top of the thirty stories.

Mr. Bolton: An inch and a half of water?

Mr. Paul: An inch and a half of mercury as shown by the gauges, or to put it in another way, with atmosphere on the main in the basement, in the cupola thirty-two stories over four hundred feet up there was in the riser a pressure of one and one-half less than atmosphere. At the last meeting I made a statement that there was no loss in eight hundred feet of main, at least it was not shown by a low pressure gauge. Since I made the statement I have found that loss by friction is much reduced in our system working at or below the atmosphere.

Mr. Bolton: Mr. President, this paper deals with a subject somewhat of interest to me and in which I have had some practice. This

very interesting question of ventilating office buildings has been up for discussion and consideration, I suppose, many hundreds of times, and it has always been thrown down on account of the amount of ground or office floor space that has been taken by the ducts. It therefore seems to me that the instance cited by Mr. Jellett is a distinct advance, and is most likely the way in which it will be eventually accomplished, as the author's arguments are entirely right in this direction. But it would be hopeless to get owners to allow ventilating flues to be put in space they can rent for $1.60 a foot, and sometimes even for $2.00 a foot. Then it has always seemed to me that the system of heating the air for such very tall buildings must be done, or will be done, somewhere on the roof of the buildings, which is the proper place; first, to get the air, and, secondarily, is the best place, in my judgment, to handle it. I have recently been making a little more use of the roof by putting a storage battery on the roof of a building with the greatest success. The argument formerly was that it was so inaccessible for the engineer; but nowadays, with the automatic devices we have, we can dispense with the engineer's attendance during the best part of the day. I had plans prepared and space laid out for an air heater and fan on top of what is now the German-American Building in Liberty street, which was designed to condense the exhaust steam at times when the building did not require it for the heating system, and that, in my view, is a system which could be adopted anywhere. In that case the power available for the purpose is not going to cost the apparatus anything, for it consists of a vent fan, which draws from the toilets through the building, and will be doing work by discharging air which might as well be passed over a series of coils and made use of to condense the steam. It would be questionable whether any particular effect would be felt back on the engine; that is to say whether we would get any vacuum or any less pressure than atmospheric pressure. But the mere saving of the water alone is an item of great importance in such a building down town, and that little item is mentioned by the author incidentally here in one of his arguments—that the cost of water should warrant such saving. The amount of water put in the tall buildings down town is curiously out of proportion to what the land upon which the building stands is entitled. A large fifteen-story building will use fifteen thousand gallons of water per day, and that water multiplied by sixty or seventy sky-scrapers down town is becoming a very serious and heavy tax on the water department's capacity, and is causing a large

cost to the city of New York to bring extra pressure down town to meet it. But inasmuch as that water has almost always to be pumped it costs the owner more than the mere dollar a thousand feet that he has to pay the city for the water itself. Incidentally I might mention that they are now putting in those buildings refrigerating plants, and in some cases are using thirty gallons a minute running over a plant of that kind and discharging into the sewer. It stands to reason that sooner or later the people of this city will get up in their might and smash people who do those things and make them use other means to attain an end which is practically putting money in their pockets at the expense of the rest of the inhabitants and taxpayers.

I have seen and several times studied the operation of the system of semi-ventilation in the Manhattan Life Building, and I have always understood it was more or less of a failure. I have been into a number of offices there at different times, and more especially on the exposed southern side, you would find those openings invariably closed, and I do not think they can be regarded as an effective means of ventilating an office. Something of a positive nature is needed, if anything at all is put in. These attempts at getting at a result at a minimum amount of cost generally lead to the discrediting of the whole system.

I come now to a point somewhat of interest to me, and that is the question of piping. I dare say some of the members of the society are aware of the great mass of piping there is in these tall buildings. As an exaggerated instance I may mention that there are 26½ miles of piping in the Bowling Green Building, and that a good deal of that is steam piping. Now, piping becomes of the utmost importance, and the author's remarks in connection with some of the errors that have been made, in steam piping especially, are fully justified, and more especially in those connections between the boilers and the mains, and the mains and the engines. I realize the difficulties there are in these confined spaces in getting a proper spring from the boiler over to the main, but when the author speaks, as he does, of running a horizontal pipe from an elbow on the nozzle of the boiler to a stop-valve bolted onto the steam main he misses the point. The point is to get a proper springing connection there. Your boiler will take care of itself. It is the water that reaches the main and travels in the main that you have to look after. Then, again, the point that the stop-valve should have its stem in a vertical position is not exactly so. There are plenty of valves that are made in which

you can pack the stem when the valve is placed in any position. On the other hand, hanging the stop-valves downward is bad practice and has been the cause of disaster. I have in my recollection, as Mr. Meyer probably will remember, a case in point. One of my specifications called for a system of steam piping, in which I had, as I think, provided properly for the springing of the connections; brought it into the engine room, placed a large steam separator; ran the main beyond the engine and at the end made a drop leg, and dripped the bottom of the drop leg. The engineer in charge left the separator out to begin with, shortened the pipe up so that the springing connections were disposed of, and took horizontal connections out of his main and put a vertical separator on each engine leg; used the same thing with the last engine in the line, so that the water might possibly go over to the last engine, and eventually did do so. Then he hung his valves, which he made of the gate pattern, all downward, so that the stems could be easily accessible. The result was that the valve was half open and a slug of water came over from the boiler one day—some one released the valve a little bit, I suppose—and a big slug of water went over to the engine and smashed things generally, notwithstanding the separator on top of the engine. The separator in the horizontal line was not there. That matter came up again lately. I was called in to see an arrangement of piping, which, I am sorry to say, had been laid out by a consulting engineer. In that case the main had been extended through a separator into the engine room, but had passed up through an opening in the wall and down into a header, which was run along the engine room, from which the branches were taken off, very properly, at the top. Any moisture that could pass the separator had no possible means of getting out unless it backed up into the pipe until at last it was carried over into one of the engines. The result was a fearful vibration. I was called in to condemn the engines and say they were unfit to run on the foundations or that they were jogging the house to pieces, but I attributed it to the pipes, and requested that a drop leg be formed on the far end and I think that will cure the matter.

I will ask your indulgence while I wrestle with the statement that the author has made that the engineers have gone a little too far in endeavoring to save the heat of steam condensed in exhaust pipes, feed-water heaters, etc. I do not think we can go too far in that way. It is necessary, as I have already said, to save all the water we can. And it is not always the case, as the author has said here, that

the steam exhausted by the plant is more than can be made use of in the building. It must be remembered that the buildings work under very variable conditions. There are hours in the day when, of course, there is a very small amount of steam used, and there are other hours in the day when the tenants open the valves and take away all the steam they possibly can. I am placing exhaust heads on the waste exhaust on the roof, with a very large surface exposed to the air, and take all the condensation that we can and bring it down to the basement. That leads directly to the statement of the author of his opinion that feed water should not be used back from drips unless a filter is used. Well, I want to say that this question of fear of oil is a very old nightmare and bugbear. We have got I don't know how many millions of tons of shipping driven by many millions of horse power. I venture to say that fifty per cent. of that is being driven by boilers that are fed with water direct back from the condenser, with all the oil that they care to get into them, and it is very rarely that we hear of trouble with boilers from oil getting into them from that cause. The very simple device of a filter tank, which is constantly employed in marine work, is nothing more than a couple of screens to catch any oil that may be floating about in this tank. In the open feed heaters that are now on the market those devices are provided. That is to say there is a perpetual overflow. The separator flows over to the waste—to the drainage, automatically. I consider that that is a matter that we have got past, and I have placed a great many open feed heaters in this city on this very service of tall buildings, which have given no trouble whatever, and there is not the remotest sign of oil in any one of the boilers after several years of service. That question can be looked into by any member of the society at any time by examining the engineers in charge, who would be more afraid of oil than anything else. The filters that are provided for that purpose do not appear to me to be worth their cost.

This question of a grease separator is an important point. In going about you will find them located in the most absurd and impracticable positions. I have had great trouble to get them placed in proper positions. A very recent instance is a very expensively constructed down town sky-scraper, in which closed feed heaters are used and a very large grease separator put on. The grease separator was put on the bend that came down from the overhead exhaust and ran into the bottom of the feed heater, and was placed down close to the floor, and the drip was run to meet the drip from the feed heater.

That is a very nice way of getting two drips to fight one another. They were both run off in a common pipe to the drain. The result was that the grease separator backed up and the grease was carried over in the steam and liberally coated the pipes in the closed heater and eventually found its way to the heating system, and worked clear through the heating system and came down into the return tank, and it was pumped back into the boiler, and four tubes came down as a result. That is an illustration of what you may do and how you may suffer from oil troubles even if you don't have an open feed heater.

The final remarks of the author on the subject of turning live steam into the waste steam I can quite imagine to be correct, because things of that sort have occurred. But it appears to me to be quite out of the question if a proper reducing valve be used. I have never experienced such a difficulty as this, but it has often appeared to me that some buildings are doing that. There is, however, a very curious effect that may be found in some of the down town buildings, and that is that they pump steam into the house system against their back pressure valve to a certain point. The engineer then loads the valve further, increasing back pressure in order to keep his steam from escaping, and he thereby puts so much more work on his pumps that they use still more steam and do the more work. So he goes on all day long piling up the agony.

The President: If there are no further remarks, Mr. Meyer will close the discussion.

Mr. Henry C. Meyer, Jr.: Mr. President: I would like to say one or two words. I got this morning, too late to be included in the paper, some figures from Mr. Wolff in regard to the cost of heating and ventilating these large buildings, and I think the experience will be valuable. He says it has been his experience that the cost of a steam-heating plant, including the engine, the piping, the radiators and the return pumps, has varied from five to seven per cent. of the total cost of the building, not including the real-estate upon which the building is constructed; that in putting in a ventilating system, in addition, the cost varied from seven to ten per cent., a difference of about two and a half per cent., which, if you include the cost of the property, will mean a very small investment for a proper ventilating system in one of our modern buildings. I want also to state that I neglected in the paper to give Mr. Wolff credit for having been consulted on the Buffalo Building. I did not know it at the time.

XUM

Turning to some of the remarks of Mr. Bolton, he states that it is difficult to get the consent of the architects to put in a ventilating system, on account of the cost of the floor area, and I think in such a system as the Singer Building and also in the Buffalo Building, the exhaust flues are certainly not over twenty feet square in section, and at $1.60 per square foot, the cost due to loss rentable floor space would amount to $32.00 per floor per year. That certainly is not very much.

Mr. Bolton: It is the owner I referred to, not the architect.

Mr. Meyer: Well, the owner. I do not agree with Mr. Bolton's statement that all of the water should be saved. Considerable of the steam that comes from the engines is condensed in the heating system, and that is returned to the boilers. Just what that proportion is, of course, varies, in different buildings. If you throw away the drip or the condensation in the low presssure mains and in the feed water heater, you throw away a very small percentage of the total amount of water used, and I think a little figuring will show that the question of cost does not amount to much. Mr. Bolton says he has had no trouble from grease and that the engineers of these various buildings have not had any trouble. I have seen this week the head of one of the largest boiler companies in the country, one which I think has put in more boilers in this city than any other firm, and he told me that they had had a very great deal of trouble from grease and that they expected a good deal more. I am very much inclined to think that they are in a better position to appreciate the trouble from grease than the men put in charge of the engines and boiler-rooms. Mr. Bolton also speaks of the marine service. I think you can hardly compare it to the conditions of a modern office building. A marine engineer cleans his oil filter just as regularly and carefully as he oils his engine, and that is how they keep oil out of marine boilers.

In regard to preferring a somewhat flexible connection between boiler and engine, of course, I would prefer and I think any one would prefer the long, flexible connections which are used in electric stations, where there is plenty of head room, but as they cannot get it in these buildings, you have to do the best you can. My purpose in putting the valve over the steam main was to keep pockets out of the system, so that water could not collect in them. I know that some boiler inspectors ask that the stop valve should be placed immediately over the boiler; I cannot see any good reason for it, for certainly, in a great many of these buildings—I know of one where

it was necessary for the engineer to crawl on his stomach in the space between the boiler and the ceiling, where there was a clearance of about eighteen inches, to close the stop-valve on the boiler. I do not think that a valve ought to be put in that location.

In regard to the amount of exhaust steam thrown away, I found out from a pretty careful investigation that all of these buildings have got more exhaust steam than they know what to do with, except from the hours of half past seven to eight o'clock in the morning on an exceedingly cold day, when it is necessary to use live steam for warming up the building. Of course, the load is light in the building at that time. I think Mr. Bolton stated at the last meeting of the Mechanical Engineers that the Bowling Green Building required considerable live steam.

Mr. Bolton: Yes.

Mr. Meyer: I think that is the only building I know of in this city that does, and the days on which they do require it are so few that it pays to put in the most economical apparatus one can get, because the coal costs just as much under the boiler of an office building as in any manufacturing establishment.

LVI.

# THE RELATION BETWEEN THE ARCHITECT AND THE HEATING ENGINEER.

BY T. N. THOMSON.

(Associate Member of the Society.)

It is unfortunate for the advancement of heating and ventilating interests that so little consideration is given to the scheme of installation while the building is in the embryonic condition. There is so much "hurly-burly" in the current methods of business that the bulk of our wisdom is included in the "backsight" instead of in the "foresight" lens of discerment, and until clear and well-defined lines of procedure are adopted in the offices of both architects and engineers little progress can be hoped for.

*Example.*—Broker Martineau calls on Architect "Sector" with the information that he has purchased a lot and wants him to get out the drawings for a four-story residence right away; in fact, a friend of his is ready to start excavating as soon as the cellar plan is out, which must be within ten days.

The architect naturally maintains that it is poor policy to talk of building cellar walls before he has thoroughly studied the requirements of the building and had sufficient time to complete the structural plans in detail, but his client feels that immediate progress must be made, and will listen to no explanations. As a persuader, he hints that Architect Todhunter is very anxious to do the work, and unless Mr. Sector can see his way to go right ahead he will have to see the other fellow. The client's patronage is valuable, and he must be humored, so the result is that Mr. Sector immediately commences preliminary studies and submits them to his chief draughtsman with instructions to push them along, as Mr. Martineau will call in three days to examine them. Before the broker and his wife, however, have made up their minds to the many details of arrangement which they wish incorporated in their residence it is found that thirty days have elapsed and the architect is still goaded by his impatient client to make a start. The office force is set to work preparing the work-

ing drawings, and the chief draughtsman, having decided on the structural requirements of the design, now turns his attention to the location and size of the smoke and heating flues, etc., provision for which must be made in the walls. He therefore consults with his superior on the proposed system of heating, but finds that the owner has not yet decided upon a system. The work must be pushed, however, and the very important matters of heating and ventilation are entirely neglected until the building is under cover. Up to this time the only provision that has been made for the heating system is a chimney flue located somewhere—generally anywhere—and it will be a miracle if this flue is not too small.

The reason why this state of affairs exists, possibly, is that the owner does not know what kind of a heating system he wants, and consequently his architect has been working in the dark; it is more probable, however, that the energies of the architectural force have been concentrated on the construction of the building, and the heating system has, therefore, been overlooked. The owner is now notified by the architect that a decision must be made on the system of heating and the contract must be let and the work started immediately, otherwise the plastering will be delayed. After many consultations between architect and owner, the latter decides that, as the design of his residence has attracted so much attention and has been so favorably commented upon, he is justified in having the very latest and most approved system of heating and ventilation installed in the building, and Mr. Sector is instructed to submit schemes for accomplishing the same, with estimates of cost.

The architect immediately calls in a few expert heating and ventilating engineers and explains to them the characteristics of the structure and certain conditions which he is desirous of having complied with. He also gives each engineer a set of blue prints and general instructions.

Of course each engineer decides upon an indirect steam or an indirect hot-water system, but when he takes a general survey of the now half-finished building the difficulties to be surmounted are so pronounced, and the expense of such an installation is so great, that he reluctantly feels like recommending the old direct-radiation method all over. It is just the old story—no provision made for anything but the chimney.

After an enormous amount of worry and scheming each engineer submits two sets of plans and specifications—one set is for direct radiation and the other for indirect radiation with the necessary outlet or vent flues and probably an aspirating stack.

XUM

The indirect plans are submitted first (the direct plans being held in reserve), and the architect is simply stunned. His practiced eye sees at a glance that this vent stack and that flue boxing, along with many other projecting monstrosities, will ruin the internal effect of the structure. The basement will be like a factory, and, in fact, the entire building will become a "hotch-potch" of pipes, flues and boxings. Something must be done so that a reasonable degree of character and style will remain in the internal treatment. Engineer and architect now consult and decide upon a "give-and-take" plan. The architect is willing to cut out here and build up a little there in order to conceal certain flues. He changes the plans somewhat to get in a central vent stack, and puts in a few more open fireplaces for the sake of ventilation. He also agrees to build an underground duct, and brick in the indirects, etc., all for appearance and general utility's sake. The engineer, on the other hand, cuts out some indirects and replaces them with direct radiation, because it would weaken walls or beams too much if the proposed flues were all run through, and so the thing goes until a fairly good arrangement is mapped out on the "trestle board." But see what it will cost to make the changes in the building; compare it with the very simple, economical and unobtrusive system that could have been devised if architect and engineer had but worked together on the first lay-out of the plans, before the construction was commenced.

This is no fable—it is an every-day occurrence, and almost every engineer can testify to it. Why is it that some of the very finest and most costly buildings in the country to-day are defaced internally by steam pipes running here, there and everywhere? It is simply because no provision was made for a better arrangement in the working drawings, and before the building was commenced.

Why is it that the basements of most large buildings look like factories? Just because the engineer came on the scene too late to have it otherwise.

Why is it that the basement of a building is not usually finished in a half-decent manner? Just because there is a general impression among architects and owners that this part of the building, at least, must be sacrificed to the several engineering contrivances now in use in all modern buildings.

Every square foot of floor surface within the walls of a building is valuable; it represents so much money invested. Every square foot of surface covered by or obstructed with engineering apparatus means just so much available rental space paid for and lost. Then

why is so much floor space wasted by machinery, pipes, ducts, casings, etc., being indiscriminately scattered everywhere? Only because the building has been built without consultation with the heating engineer and the other engineers.

The science of building construction extends over such an enormous field of operation, and covers such a large number of industries, that no one man can possibly be master of all the crafts. It therefore is foolish to expect an architect, or, in fact, any other human being to design a modern building without the assistance of experts well versed in the several branches of the building trades and equipment.

Architects are not blind to this fact, and nobody knows that better than we do; they all prefer consultation with the engineers before the working drawings are made, because they know how much can be saved and how superior the results will be when all installations are carefully considered in detail and accurately mapped out before the cellar walls are built. But this treatment of a building is seldom resorted to except by a few of the leading architects.

I wish that all the architects in the United States could have an opportunity to read this paper so that they might be reminded of the fact that a world of difference exists between the "forethought" job and the "afterthought" job. The former is a modest, unassuming, semi-concealed, and entirely accessible system which does not stand pronounced at any place, yet perfectly and imperceptibly performs the functions of its office, so to speak. When strangers go through a building which is finished with a *forethought* job of engineering they are usually impressed with the magnitude and grandeur of the interior, and they marvel at the conspicuous absence of the customary eyesores. But in a building which, unhappily, is provided with an *afterthought* system of heating, a peculiar feeling of unrest seems to prevail throughout. Everything appears to indicate to the man of structural ideas that great scrimmages must have existed between the contractors for place, and that the architect has been a secondary man on the building. To the uninitiated, of course the chaos is unexplainable. They say the building is fine but for the pipes, etc., which are so numerous and prominent that they cannot see anything else, and are located in such a way that there is no place for furnishings. To those of refined feelings and sensitive temperaments the beauty and grace of the buildings are lost in the medley of steam pipes and promontories of modern engineering contrivances.

Do the owners of buildings want all this "jumbleation" of mon-

strosities? No. Do the architects want it? No. Do the engineers or contractors want it? No. Then why should it exist? This question, gentlemen, I leave open for you to decide.

DISCUSSION.

The President: There is not much chance to discuss this matter because we all know it is a fact. The only thing that we could possibly discuss it seems to me is how to get the other fellow to know it. The paper might be sent to the American Society of Architects or something of that kind.

Mr. Kent: And have the architectural journals take it up?

The President: That course could be pursued.

Mr. Kent: A couple of years ago I was walking down Broad street, Philadelphia, and I saw a tall building there, not quite finished. There was a sign outside "For rooms and offices, apply to Mr. So-and-So," and I recognized the name of a well-known mechanical engineer whom I had not met in ten years. I wondered if it was the same man. I went into the building and there was the man, and he was superintending the construction of the building. I said, "Have you become an architect?" "No," he said, "I am an engineer. This building is built by an engineer, and it is all engineering from beginning to end except the front on the street. For that I employed an architect." The owner had employed this engineer to design and construct that building. It was an engineering structure entirely—the foundations, the ventilation and heating, the boilers and engines, the refrigerating plant—all the iron work was engineering and all the architect had to do was to design the front to make the building look pretty. That is what it will come to. The architect and engineers will have to combine. There will be an engineer in the firm as well as an architect. Then things may go a little better. Another trouble about the thing is the commissions paid. The architect has been in the habit of charging 5 per cent. commission for his services, and in case of large jobs he might reduce that to 2½ per cent., and the owner thinks that is all he has to pay. Then the heating and structural engineers and the other engineers are called in, and they want the same fees as the architect. The architect does not like that, and the owner does not like that—it is too much. There should be some conference—some study of the subject as to what should be the legitimate fees for the various branches of engineering that enter into the structure; how much the architect ought to get and how much the engineers

ought to get. The engineers should come in as architects in that matter, and they really are architects in so far as they work on buildings.

Mr. Bolton: Mr. Kent has struck really the heart of this matter, and I would like to say that if this paper is going to the architectural profession it wants a considerable addendum to it, because there is more of the subject than appears from the author's remarks. The real answer to his question is, that he can get all this work done by doing just as he suggests, by calling in a few heating and ventilating engineers from the trade and get them to prepare plans. They will do it for nothing. Of course, you will understand I am speaking with a personal feeling in this matter, and I trust you will excuse any little warmth. It is actually the case that that is being done. Now I have in my possession plans that have been eventually turned over to me, which have been extracted from the heating and ventilating trade at a cost I should imagine of many hundreds of dollars, and no one of which had any possible chance to secure the work. It was simply gotten out of them in order that the architect might get the ideas. I have been in architects' offices doing work for them on their tables and I have seen that done, so that I know that that is what is going on in this city. It is not fair I contend for an architect who is constructing a building, a certain portion of the work in which he knows about, and knows nothing about the remainder, to get out of a body of men, who do understand it, for nothing, and for less than nothing, the information that he lacks. As Mr. Kent has said, architects are cutting their fees down in these days of competition, and in order to secure as much as they can of the work, they will insist upon the entire work being placed in their hands; their percentage to be based on that. The result is that they won't hear of parting with any portion of that fee to any engineer who wishes to help them, and they expect the trade is going to help them out by giving them the information for nothing. It is more and more the case as years go on, that the mechanical appliances in these buildings are assuming greater importance than the mere architectural features in the building itself. The work with which I have to do represents now a little over one-seventh of the value of any building outside of the cost of the real estate, and if the steel structure were taken into account also it would probably average very near 50 per cent. Therefore the work that the architect has to do is gradually becoming of a very limited character, and he is getting into the position more and more as years go on of being nothing but an agent whose duty it is to collect

information and bring it together in the shape of a building. I think the architectural profession have a great deal to repent of in this matter. They are trying to do work that they are not qualified to do, and if engineers undertook to do the same thing and designed Ionic and Doric fronts for buildings they would deserve as a profession to be kicked down. But architects are doing that all the time. They profess to be experts on every subject that comes up in a building, which they cannot by any course of reasoning be expected to be.

The President: The smaller the architect the more that is the case.

Mr. Bolton: It is a case of greed.

The President: The unfortunate fact is that what you say is true, and there is no one to blame but ourselves.

Mr. Bolton: One of the objects of our society, as I read it, was to take means to insure proper remuneration for designs that are made by members of the society. That has always appeared to me to be a very proper object for the society.

Mr. Jellett: I would like to say a little on this particular subject as I am especially interested in it. This question that Mr. Bolton touches on is the basis of the relationship between the architect and the engineer, and it has grown up through a period of years largely from the fact that the heating and ventilating men were all in the contracting business some years back when the custom started. There were then very few if any consulting heating and ventilating engineers in this country. All of that work should be kept out of contract work. I have talked the question over with a number of leading architects, members of the Institute of Architects. A short time ago I met three or four of them and we talked up the whole subject. One of them said, "I will explain it to you from my standpoint as an architect. It is a case of live and let live. When our commission of five per cent. was fixed by the Institute of Architects a good many years ago, there was no steel structural work in buildings. There were no fifteen story buildings and comparatively few buildings had elevators. There were boilers put in the cellars and some wrought iron coils or radiators put around the building. There was very little engineering design that entered into the building. So that we got five per cent. on the total cost of the building. The walls were masonry, and the construction was necessarily expensive. The present type of building increases land values very much, but we have to call in to assist us the structural engineer, the electrical engineer, the

heating and ventilating engineer, and in some cases the hydraulic and refrigerating engineers. Now if we take out of our five per cent. the amount of construction that is left under those plans and specifications we would get the five per cent. on about forty per cent. of the total structural expense, and where does the architect come in? We used to get five per cent. on $100,000. If we pay these men out of our fees we get five per cent. out of $40,000, and yet we are supposed to look out for all these men. So that from the architect's standpoint we are in a pretty bad way. Either the owner should pay the additional engineers' fees or squeeze it out of the trade." I asked him if he had ever tried to get it out of the owner. He said, "On one or two occasions I have, and the effort was repulsed so suddenly that I did not try it again. But the matter is coming up before the Institute of Architects. The engineers should be under the direction of the architect. The architect being the designer, the creator of the building, all these men should work in harmony with him. But the object in getting these engineers is to get the modern ideas and to reduce cost. Now we are reducing the cost not for the architect but for the owner, and he is the man who should pay for it." The argument, I think, is a perfectly fair one. We who are in the contracting business can help to that end by refusing to make plans and specifications in competition; that is, as bidders. We will make you plans and specifications if you come to us, but we will charge you for them as consulting engineers. That means within a short time a man naturally will go to a consulting engineer. In our own particular business in Philadelphia we started some years ago to charge for plans and specifications. We do it yet. At that time there was not a single engineer in the city of Philadelphia that did consulting work in connection with heating and ventilating a building. There are now two or three, and they are getting the business gradually. We do lots of that sort of work, but we charge for it just the same as if we were only consulting engineers and did not undertake contracts. Architects frequently say suppose we give you the work, do we pay for the specifications? Certainly. If I was simply making you a plan for the opportunity of securing the work I would not make the careful study for the owners and your interest that I do as an engineer. I had one illustration of that a short time ago. I was told when we started the system that it was not possible to get an architect to pay us for engineer's services. I said I did not think that was correct. The reason why it was not possible to get pay for such services was that nobody asked for it and the man that

does not put value on his own work must not expect anybody else to do it. I was sent for by an architect for whom I had not done any work. He said, "I want you to make plans and specifications for a certain building." I said, "Shall I charge you a percentage on the whole thing or do you prefer that I should approximate the cost and name a lump sum?" He said, "I did not expect to pay for it." I said, "I do not expect to give it to you." He said, "The trade generally do that sort of work for architects." I said, "I know that is the custom but it is not right. For this particular building the plant will cost approximately $20,000; you are getting five per cent; you are getting a thousand dollars for what you want me to do for nothing. Do you think you are an object of charity? Are you making your plans for nothing?" He said, "No." "Then," I said, "why should I make part of them for nothing?" He said, "I never thought of that before." I said, "Put it in another way. What right have you to expect me to spend three or four hundred dollars of money that I have earned from other contracts for your account? Every man's business must pay a profit or wind up; one or the other. Now then is it fair that I should earn money from John Smith and turn around and give it to Jones simply to help him out? I don't see any reason in that at all and I won't do it." He said, "I never considered it in that light; I would like to think about it." I said, "Put it in another way. If I do this for nothing you are under obligations to get me that work." He said, "No, sir." I said, "You are, if you are a fair man; you are under obligations to pay me in some way, and you know it. You are either going to do what you ought to do to me by getting me that work or you are going to treat me in a way that you have no right to treat me; one or the other. Now it may not be to the interests of your client to give me that work. You must either go back on him or ill use me; one or the other." He said, "I would like to see you again later." He sent for me about a week after and gave me an order. He said, "It is the first time I paid for an engineer." I said, "I hope it will not be the last time, because I believe you will be a more independent man than ever before." I have since done for that man a good deal of engineering work, and I do not believe that any man will get a price for his work if he does not ask for it. I think that is the only way to get it.

Mr. Bolton: I think Mr. Jellett's experience adds very materially to the paper, and if those remarks had been added to it the paper would have been more valuable as an expression of the society's feeling on the subject.

LVII.

# SOME EXPERIMENTS WITH CENTRIFUGAL FANS.

BY WM. S. MONROE, CHICAGO.

Some months ago the author, in connection with Mr. George H. Barrus, of Boston, was required to make a very complete test of the ventilating system of the Chicago Public Library, and in connection with some changes which were in consequence necessitated, had an opportunity to make a few experiments on some large centrifugal ventilating fans, and he has been urged by some members of the Society that it would be of interest if the result of these be presented at this meeting. In doing this I beg to apologize for the fact that the experiments were not completely carried out, partly on account of the conditions at the Library, and partly because of lack of time since having promised to write this paper.

The ventilating system at the Library consists of fourteen large centrifugal fans, all being located in the basement of the building, one-half of the number being supply fans, the other, exhaust. There are two large intakes through which the air is drawn from a height of about forty feet from above the ground, one intake supplying four supply fans, the other three. The air is blown into the various rooms in the building by ducts from these supply fans, and exhausted through another system. The ducts from each fan are independent of those from the others, there being no connecting chamber.

Each of the blast fans is provided with a heating stack, and by-pass, the dampers in the latter being regulated in cold weather by automatic thermostats. The principle dimensions of all the fans which may be of interest are presented in the accompanying table:

TABLE A—DIMENSIONS OF FANS—C.P.L.

SUPPLY FANS.

| Fan | A | B | C | E | F | D | G |
|---|---|---|---|---|---|---|---|
| Diameter of wheel (inches) | 92 | 92 | 106 | 78 | 78 | 78 | 78 |
| Diameter of inlet (inches) | 65 | 65 | 74 | 54 | 54 | 54 | 54 |
| Width of blades (inches) | 56 | 56 | 45 | 45 | 45 | 45 | 40 |
| Expansion of casing (inches) | 56 | 56 | 45 | 45 | 45 | 45 | 40 |
| R. p. m. (nominal) | 53 | 53 | 45 | 70 | 70 | 59 | 52 |
| Heater coils—width | 8' 6" | 9' 6" | 6' 0 | 6' 6" | 7' 6" | 7' 6" | 5' 0 |
| " " height | 6' 4" | 6' 4" | 6' 4" | 5' 4" | 5' 4" | 5' 4" | 5' 4" |
| " " square feet surface | 9,800 | 10,400 | 6,000 | 7,200 | 7,200 | 7,200 | 4,200 |
| Area by-pass (square feet | 35 | 35 | 18 | 16 | 16 | 16 | 12 |
| H. P. Motor | 3 | 5 | 3 | 5 | 5 | 3 | 1 |

EXHAUST FANS.

| Fan. | O | P | Q | R | V | S | T |
|---|---|---|---|---|---|---|---|
| Diameter of wheel (inches) | 92 | 92 | 78 | 92 | 87 | 106 | 106 |
| Diameter of inlet (inches) | 65 | 65 | 54 | 65 | 60 | 74 | 74 |
| Width of blades (inches) | 56 | 56 | 45 | 56 | 58 | 45 | 45 |
| Expansion of casing (inches) | 56 | 56 | 45 | 56 | 58 | 45 | 45 |
| R. p. m. (nominal) | 53 | 61 | 64 | 64 | 68 | 43 | 45 |
| H. P. Motor | 5 | 5 | 5 | 5 | 5 | 3 | 2 |

The size of main delivery duct from each fan is equal to expansion of casing by the width of blades.

It should be stated here that the building, which is one of considerable magnitude, is heated by direct radiation throughout which is figured amply large to take care of all heat radiation by glass and wall surface. The ventilating system therefore is intended merely to supply air for ventilation purposes, and not for heating. The two largest rooms in the building are those known as the Reading and Reference rooms, the former being a room of 221,000 cubic feet capacity, and the latter of 161,000. It was found that the ventilation in several parts of the building, but especially in these rooms, was entirely inadequate for the requirements, and investigation showed that the air delivery from fans was insufficient, the ducts and registers being of ample size. The fans were all run at what would seem to be unusually slow speed, ranging as shown by the above table from 45 to 75 R. P. M. and after some investigation it was decided to increase the speed of such fans as supplied or exhausted air from the Reading and Reference rooms. This included supply fans C, E and F, and exhaust fans R, I and U. It should be understood, however, that the fans supplied several other of the smaller rooms as well as the Reading and Reference rooms. The fans were all driven by electric motors connected to the fan shafts by double reduction gears, and in increasing the speed it seemed preferable on account of the noise which any increase in speed of gears would undoubtedly make, to do away with these and connect fans and motors by means of a system of belt transmission, each motor driving a small counter shaft, and thence back to the fan. On account of expense, it was desired as far as possible to use the same motors, and was therefore a matter of some question as to how much increase in speed could be attained without exceeding the rated capacity of the motor. The motors on all the fans under consideration, excepting that on fan C, were of five horse power capacity, rated for 19 amperes at 220 volts, the motor on fan C being a three horse power raised at 12 amperes. All of these motors were provided with starting boxes and speed regulators operating by resistance on the armature circuit. It was found by investigation with an ammeter that all of the motors were using, at

full speed, but a very small percentage of their current capacity, the maximum being on fans E and U, which were taking about 3.6 amperes.

From the results of the tests, it was considered desirable, if possible to increase the delivery of the three supply fans about 2¼ times, and to double that of the exhaust fans. Inasmuch as the power required to force air is theoretically proportional, other conditions being the same, to the cube of its velocity, it seemed a matter of doubt whether the capacity of the motors would allow for such increase. Reflection will show that in the case of a fan under speed it is very difficult to ascertain the power due to friction, etc., and it is evident that a considerable portion of the power at this slow speed was due to such losses. It was therefore decided to take one of the fans (E being selected) and increase the speed of this as much as practicable, and base the increase in speed for the others upon the results obtained for fan E. A careful calculation was made of the probable friction, and other losses of fan E and its connection under the conditions of running. This calculation indicated that the fractional power was equal to that represented by the consumption of 2.3 amperes at 220 volts. The fan using 3.3 amperes at the time of the investigation left one ampere required for driving the air. It was found by experiment that the air delivered increased proportionately to the speed of the fan, and it was assumed that the friction power would also increase proportionately to the speed while that required to drive the air would increase as the cube of the speed. Therefore in order to increase the speed of the fan 2¼ times would give the following:

| | Amperes. |
|---|---|
| Current to drive air ($2.25^3 \times 1$ amp.) | 11.5 |
| Current for friction ($2.25 \times 2.3$) | 6.2 |
| Total | 17.7 |

The belt transmission was therefore designed to increase speed of this fan 2¼ times at the maximum speed of the motor, and being tested after its installation it was found to attain this increase in velocity required 20.6 amperes, showing that the friction of the fan had been assumed slightly too high, a very small error in this assumption making the considerable difference in the increased power. The speed of the other fans, except fan C, was calculated in due consideration of the results obtained on fan E; the results obtained were very close to the calculations. A new pulley was subsequently put on the counter shaft of fan E so as to bring the maximum speed of the fan within the capacity of the motor. Fan C presented an entirely different problem. A calculation showed that the three horse

power motor would be insufficient to do this work. On account also of local conditions of this fan it was quite impracticable to install a belt transmission so that a new slow speed five horse power motor was secured and connected to the fan by single reduction gear with a rawhide pinion.

In thus speeding up these fans it seemed quite an opportunity to make some investigation under actual working conditions of the relations between speed of air, pressure of air and power required. Some tests were made therefore on fans E and F before the speed was increased, and after, with a view to noting these relationships at different speeds. The speed was varied by means of the controlling rheostat within the entire range available, so that taking the tests before and after the increase of speed a considerable range was obtained. The power used was measured in amperes by an ammeter on the mains to the motor, the voltage being accepted as constant at 220, there being but a very slight variation from this. In reading the amperes, however, the voltage lost in the controlling rheostat was also measured, and an equivalent deduction made for this loss so that the efficiency of the motor might be considered the same at all speeds. The speed of the fan was taken by an ordinary speed indicator, and pressure of air under which the fan was working was obtained by means of a Barrus differential draft gauge which multiplied the pressure in inches of water by four. One side of the draught gauge was connected to the main delivery duct of the fan, the other side to the suction chamber between the fan and the heater, there being on each fan a considerable space here which was accessible by means of a tight door. By detaching the tube connecting to the suction side of the fan, the excess of pressure in the main supply duct over that of the atmosphere could be read, and by detaching the other tube the suction force required to draw air through the heater and intake could be separately measured. The algebraic difference of these two represented the total air pressure under which the fan was working, which was read directly on the gauge by connecting up both tubes. The speed of the air was taken at the inlet of the fan by means of an anemometer, this being obtained by an observer who stood in a corner of the space between the heater and fan inlet, and obtained the average velocity by moving the anemometer supported on the end of a wooden arm around the entire area of the inlet. These speeds were always obtained by one minute observations, and repeated at least once for the purpose of checking. The results of these tests on the two fans are presented in tables *B* and *C*.

## TABLE B.

Fan E—Diam. wheel, 78″; width of blade, 45″.
Diam. inlet, 54″; *net* area, 13 1 sq. ft. Main duct, 45″ x 45″; area, 14.1 sq. ft.
*Gross* area heating coil, 34 7 sq. ft.; heating surface, 7,200 sq. ft.

| R.P.M. Fan. | Pressure of Air in oz. per sq. in. | | | Velocity of Air. | | Cu. Ft. Air per Min. | Net Amperes Current. | Approx. Temp. of Air Through Fan. |
|---|---|---|---|---|---|---|---|---|
| | Suction. | Blast. | Total. | Inlet. | Main Duct. | | | |
| **Geared Transmission.** | | | | | | | | |
| 6 71.5 | .... | .... | .... | 815 | 755 | 10,600 | 2.3 | ... |
| 8 74.2 | .... | .... | .... | 900 | 835 | 11,750 | 2.4 | ... |
| 10 76.5 | .... | .... | .083 | 930 | 850 | 12,000 | 3.1 | ... |
| **Belt Transmission.** | | | | | | | | |
| 3 102 | .... | .086 | .173 | 1,230 | .... | .... | 6.2 | ... |
| 5 110 | .144 | .086 | .230 | 1,430 | 1,330 | 18,700 | 8.6 | ... |
| 7 137 | .... | .115 | .302 | 1,700 | 1,580 | 22.300 | 13 | ... |
| 9 152 | .259 | .144 | .403 | 1,870 | 1,740 | 24,500 | 17.3 | ... |
| 10 157 | .... | .144 | .403 | 1,920 | 1,780 | 25,100 | 20.6 | ... |
| **By-pass Closed.** | | | | | | | | |
| .. 77 | .151 | .029 | .180 | 621 | 580 | 8,180 | 2.9 | 65 |
| .. 77 | .165 | .007 | .172 | 650 | 605 | 9 500 | 3 | 130 |
| .. 77 | + 180 | —.015 | .165 | 690 | 640 | 9,010 | 2.9 | 160 |
| .. 144 | .... | .052 | .310 | 1,120 | 1,040 | 14,650 | 12 | 65 |
| .. 164 | .334 | .086 | .420 | 1,420 | 1,320 | 18,670 | 19.2 | 65 |

## TABLE C.

Fan F—Diam. wheel, 78″; width b'ades, 45″.
Diam. inlet, 54″, *net* area, 13.1 sq ft. Main duct, 45″ × 45″; area, 14.1 sq. ft.
Gross area heating coil, 40 sq. ft., heating surface, 7,200 sq. ft.

| Speed of Fan. | Pressure of Air in oz. per sq. inch. | | | Velocity of Air. | | Cu. ft. of Air per min. | Net Amperes Current. |
|---|---|---|---|---|---|---|---|
| | Suction. | Blast. | Total. | Inlet. | Main Duct. | | |
| **Geared Transmission.** | | | | | | | |
| 1 58 | .... | .... | .043 | 680 | .... | ..... | ..... |
| 3 69.5 | ... | .011 | .035 | 786 | .... | 10,300 | 2.4 |
| 4 71 | .041 | .017 | .058 | 802 | .... | 10,500 | 2.6 |
| 6 72.5 | .... | .023 | .06 | 851 | 790 | 11,200 | 2.7 |
| 8 74 | .044 | .026 | .070 | 812 | 754 | 10,650 | 2.9 |
| 10 76 | .... | .026 | .068 | 847 | 786 | 11,050 | 3.05 |
| **Belt Transmission.** | | | | | | | |
| 1 73 | .040 | .026 | .065 | 788 | 730 | 10,320 | .... |
| 2 85 | .054 | .032 | .086 | 945 | 830 | 12,380 | 3.36 |
| 3 100 | .068 | .040 | .108 | 1,093 | 1,020 | 14,320 | 5.16 |
| 5 114 | .123 | .053 | .176 | 1,240 | 1,150 | 16,250 | 7.11 |
| 7 123 | .... | .061 | .... | 1,350 | 1,255 | 17,680 | 8.88 |
| 9 139 | .... | .075 | .... | 1,520 | 1,415 | 19,900 | 12.1 |
| 10 143 | .... | .075 | .... | 1,590 | 1,470 | 20,650 | 13.5 |
| **By-pass Closed.** | | | | | | | |
| 76 | .071 | .011 | .072 | 554 | .... | 7,260 | 3.05 |
| 141 | .... | .043 | .257 | 1,075 | .... | 14,080 | 11. |

A fairly complete test was made on each of these fans with the by-pass wide open, and the heater cold. The temperature of air through the fan being between 60 and 70. Some few tests were also made with the by-pass closed, and on fan C with varying amounts of the heating coil turned on so as to observe the effect of closing the by-pass, also of increasing the temperature of air through the fan.

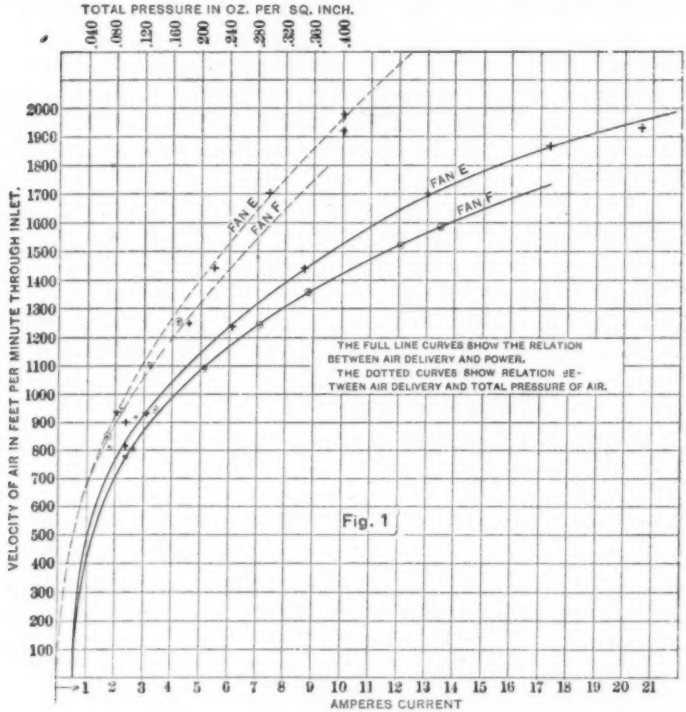
TOTAL PRESSURE IN OZ. PER SQ. INCH.
.040 .080 .120 .160 .200 .240 .280 .320 .360 .400
VELOCITY OF AIR IN FEET PER MINUTE THROUGH INLET.
2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000 900 800 700 600 500 400 300 200 100
FAN E
FAN F
FAN E
FAN F
THE FULL LINE CURVES SHOW THE RELATION BETWEEN AIR DELIVERY AND POWER.
THE DOTTED CURVES SHOW RELATION BETWEEN AIR DELIVERY AND TOTAL PRESSURE OF AIR.
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
AMPERES CURRENT

Fig. 1

I have plotted curves (see Fig. 1) showing the relation between the velocity of air and the power required in amperes of current for the result with open by-pass. I have also plotted on the same diagram the relation between total pressure and velocity of air. It will be seen that the velocity curve is very uniform and very regular, and it will be noted from this also the great increase of power that is required for small increase in velocity after the curve begins to bend toward the horizontal. The points on the pressure curves are much more irregular, this being due to the fact that the pressure is very small and difficult to measure with the gauge used on account of a

slow vibration. A small error in reading also made a large proportional difference.

I have also plotted (see Fig. 2). curves showing relation between the power required and the cubes of the air velocity. These should be theoretically straight lines and the points obtained show them to be practically so, as in platting them any errors of observation are greatly multiplied. It may, however, be noted that these latter curves do not pass through the origin. This is doubtless due to the fact that the power recorded includes the friction of the mechanism and that the efficiency of the motor increases somewhat with the speed. But the fact of these points indicating straight lines shows also that the friction varies practically in direct proportion to the speed.

The attention of the Society is called to several points of interest in these curves, and referring to Fig. 1 it will be noticed that in the first place the two fans E and F are exactly of the same dimensions, but that the delivery of the fan E is uniformly higher than that of F.

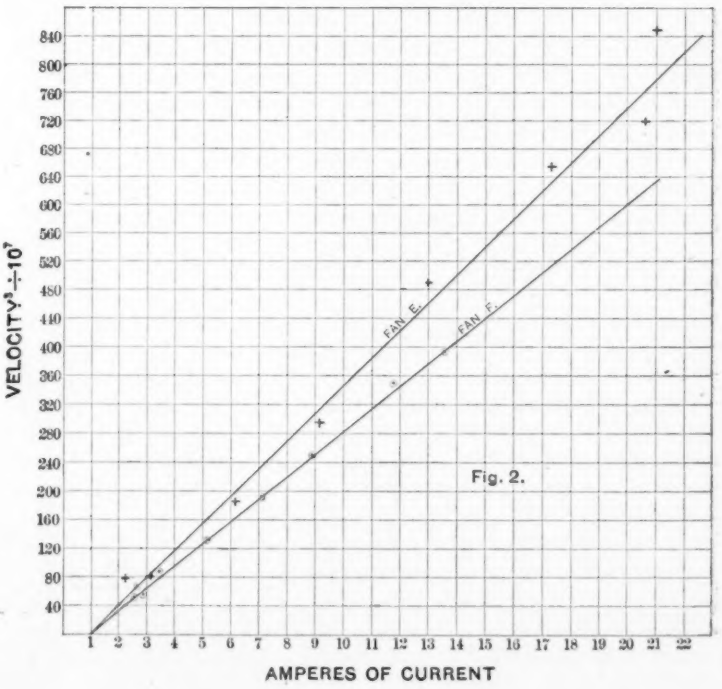


Fig. 2.

It will be seen also that the pressure curve of fan F is higher than that of fan E for the same velocity, showing of course that the resistance of the ducts, etc., of fan F was somewhat more than those of fan E. Mr. M. C. Huyett recently published a valuable table of centrifugal fan capacity, and it is interesting to compare capacities given in his table with those actually obtained on these fans. Mr. Huyett's table is based on the assumption that the delivery of such fans is proportionate to their speeds, other conditions being equal, which is true for all practical speeds, and his table for a fan of the size of the two under consideration gives 166 cubic feet of air per minute per revolution of fan. The results on fan E give 165, and those on fan F 144. Mr. Huyett's table, as he expressly states, is for free delivery, that is with practically no air resistance except the fan itself.

It may be taken therefore that the resistance on fan E was very slight or practically no more than allowed by Mr. Huyett in his table. It will be noticed, however, that a very slight increase in the air resistance will materially decrease the fan output. In this connection also I would state that some anemometer tests on fan C gave a delivery of only 148 cu. ft. per revolution of fan, whereas Mr. Huyett's table gives 307 for a fan of that size. It is much to be regretted that it was impossible to take observations of the air pressure on this fan, but the resistance was undoubtedly high.

Another point which will be of interest will be found in the reduction of air delivery due to closing the by-pass around heater. A comparison of the results on both the air deliveries and power required

TABLE D.

Showing effect on air delivery and power of closing by-pass.

| (1) R. P. M. Fan. | (2) Vel. Air, By-pass Open. | (3) Vel. Air, By-pass Closed. | (4) (3) ÷ (2). % | (5) Current Requd., By-pass Open. | (6) Current, By-pass Closed. | (7) (6) ÷ (5). % | (8) Amperes for Vel. in (3), By-pass Open. | (9) (6) ÷ (8). | (10) Approx. Temp. Air Thro' Fan, By-pass Closed. Degrees. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | FAN E. | | | | | |
| 77 | 935 | 621 | 66.3 | 3.2 | 2.9 | 91. | .... | .... | 65 |
| 77 | 935 | 659 | 69.5 | 3.2 | 3.0 | 94. | .... | .... | 130 |
| 77 | 935 | 690 | 74.0 | 3.2 | 2.9 | 91. | .... | .... | 160 |
| 144 | 1,800 | 1,129 | 64.0 | 15.5 | 12.0 | 77.5 | 4.9 | 2.44 | 70 |
| 164 | 2,050 | 1,420 | 69.1 | 23.8 | 19.2 | 80.6 | 8.4 | 2.3 | 70 |
| | | | | FAN F. | | | | | |
| 76 | 880 | 554 | 65.1 | 2.9 | .... | .... | .... | .... | .. |
| 141 | 1,550 | 1 075 | 69.0 | 12.5 | 11.0 | 88.0 | 4.7 | 2.35 | 70 |

for open and closed by-pass is presented in Table *D* from which it will be seen that the air delivery was decreased from 21 to 36 per cent merely by closing the by-pass. Two tests on fan E with part of the heater turned on, and a high temperature through the fan gave a somewhat less reduction. But even with the by-pass closed, and even at a high temperature as 160°, the delivery was 20 per cent less than with the by-pass open. The only tests at these high temperatures were made with very low fan speeds, and the test of 160° showed a negative pressure on the blast side of the fan, due to the draft of the hot air in the vertical ducts. I regret that it was impossible to repeat these temperature tests at higher fan speeds, but they do not have much bearing on practical results as temperature in air ducts of much over 100° would not be good practice anywhere. It will be noted also that whereas the delivery of air is reduced about 24 per cent by closing the by-pass the power required (for same speed of fan) is reduced only from 9 to 22 per cent, while it will be seen that for *equal air deliveries* the power was increased from *2.3* to *2.44 times* by closing the by-pass.

Attention should also be called at this point to the fact, as shown by the pressure observations in Table B and C, that even with the by-pass wide open the resistance due to intake and passages through and around the heater, or in other words the total resistance on the inlet of the fans, was in all cases quite considerably more than the total resistance of the delivery ducts, dampers and registers. This was a matter of considerable surprise as the intake seemed to be of ample size, and area of the by-pass large. It was probably due, however, to the height of intake, and as such resistances are very often but little considered it will be valuable to note their importance in this case.

As above stated, I regret very much that these experiments were not made more complete, especially that a greater number and more accurate observations were not made on the pressure, but at the time the work was done I had no idea of publishing the results. I should like especially to have had more observations of the air pressure on fan F, and also to have taken some from fan C. Those on fan F are very limited, and I have reason to believe that the blast pressure as observed was somewhat too low, inasmuch as it is impossible to reach the center of the air current from the fan. Moreover the instrument used for measuring this pressure was one made for use on boiler tests, and was not well adapted for accurate reading of low pressures or sensitive variations such as were encountered in these tests. I trust, however, that the results here presented will be found

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of interest, and will give some suggestions of practical value to the members of the Society.

DISCUSSION.

Prof. Carpenter: Mr. President, I will say merely a word. The paper, I think, presents some valuable data in regard to fans in places working under usual conditions. I would also call attention to the fact that the rule which I gave for capacity agrees very closely with the results given in Table C. I have not had time to figure the results in the other tables.

Mr. Meyer, Jr.: There is one point in regard to this paper which does not appear in it which I think may be of interest. The work done in this paper was contained in a test by the author, who was associated with Mr. George H. Barrus, both being engaged by the officers of the Chicago Public Library to make this test. They did so and found that in some parts of the building the air supply was insufficient and by a very cheap and simple method, that is by speeding up the fans, they were able to bring them up to the required capacity. I think there was nothing whatever wrong with the apparatus but this point is interesting as showing the value of expert investigations of plants after they have been installed.

The President: If the outside public could be convinced of that it would be well for the society probably. It is a very good suggestion.

Prof. Carpenter: Mr. President, if I should have the indulgence of the society one moment I have found what I think must be an error in the paper of Mr. Monroe and I just found it by calculation. In the calculation of the capacity of fan C in the paper by Mr. Monroe it will be noted he says on page 124 that the delivery is 148 cubic feet per revolution of fan. That fan, I notice from the proportions given on page 117, has about standard proportions of ventilating fans, and is 106 inches in diameter, but you will find that it shows less capacity per revolution than the smaller fans of which a test is given on page 121. Thus the fan-wheel E, diameter 78 inches, delivers for 110 revolutions 18,700 cubic feet. By my rule it would give 18,600. Now that figure divided by 110 gives about 170 cubic feet per revolution for a fan 6½ feet in diameter. Yet he states later that a fan practically 9 feet in diameter delivers only 148 cubic feet. There must be some mistake, as both results are impossible.

Mr. Monroe (added since the meeting): In response to Prof. Carpenter's remarks, the writer wishes to state that there is no mis-

take in the figures given for Fan C. We regret that the tests on this fan were not complete enough to publish, but they were sufficient to show conclusively that under the conditions in which it was running it delivered only 148 cu. feet per revolution of the fan, although the smaller fans E and F gave 165 and 144, respectively. This was undoubtedly due to the fact that there was much more resistance in the ducts on Fan C, and it was consequently working under a much higher pressure. If Prof. Carpenter had looked over the paragraph preceding the one on page 124 which he criticises, he would have noticed that the point it was desired to bring out is that the delivery of a fan is very greatly affected by the resistances and consequent pressure against which it works. This is of course a well-known fact, but the tests on Fans E and F, which are exactly the same size, show that the very slightly increased pressure on Fan F reduced the delivery by over 10 per cent. from that of Fan E.

Professor Carpenter calculates 170 cu. ft. per revolution as the capacity of a fan the size of E and F. Mr. Huyett's table, before referred to, gives 166, and the writer's tests on Fan E gave 165. But this, as stated, is practically a free air delivery, that is with the resistance in the ducts but slight as compared with that through the fan itself. In the tests on Fan F, where the pressure on the blast side was somewhat higher, the cu. ft. per revolution was 10 per cent. less. The low delivery per revolution of Fan C was undoubtedly due to its working against a comparatively high pressure.

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## LVIII.

# SOME FORMULAS FOR DISK FANS.

BY PROFESSOR J. H. KINEALY.

(Member of the Society.)

I have been trying for a long time to get some formulas for disk fans that would be of practical value in designing. I cared little about the pressures produced by the fans, as I knew that such fans are not adapted for working against pressure, and that whenever they are used the entry and exit for the air should be made as direct and free from obstruction as possible. What I wanted were really but two formulas: one to enable me to determine the proper number of revolutions at which a fan of a given diameter should be run; and the other to enable me to determine the number of cubic feet of air which a disk fan of a given diameter ought to be expected to deliver per minute when working with a practically free inlet and exit.

It would seem that, when one would be satisfied with two such apparently simple things in the way of formulas, it ought to be easy to obtain them. But I have found it extremely difficult to get anything to suit me. I have found several formulas based upon theoretical reasonings, but they always involved some constant or other which I was unable to determine.

After a good deal of work I have deduced the following formulas which I submit to the consideration of the society:

Let D be the diameter of the fan in inches and N the number of revolutions at which it may be run per minute. Then

$$DN = 21{,}000 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This formula enables us to determine the number of revolutions at which a disk fan of any type, either straight vaned or curved vaned as the Blackman fan, may be run. It is based upon the fact that the speed at which a disk fan may be run depends only upon the stress set up in the vanes by the centrifugal force. We know that a cast iron wheel may have a peripheral velocity of from 80 to 100 feet per second without undue stresses being set up. And

the peripheral velocity in feet per second of a fan whose diameter in inches is D, when making N revolutions per minute, is equal to $\frac{3.14\ DN}{12 \times 60} = \frac{DN}{229}$. If we say that this shall be equal to 90, we have

$$\frac{DN}{229} = 90, \text{ or}$$

$$DN = 21{,}000, \text{ about.}$$

The maximum number of revolutions at which a fan should be run may be taken as about 10 per cent. greater than given by the formula.

When a disk fan with straight vanes, set at an angle between 40 and 45 degrees, revolve just outside of a delivery tube whose diameter is slightly greater than the diameter of the fan, the number of cubic feet of air delivered by it per minute is given by the formula

$$C = 7\ D^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

C is the number of cubic feet of air delivered per minute, and D is the diameter of the fan in inches.

For a Blackman fan revolving just at the entrance of the delivery tube we may say

$$C = 11\ D^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Formula (2), for fans with straight vanes, is based upon the results of experiments made by W. J. Walker, given in a paper on Propeller Ventilating Fans read before the Institute of Mechanical Engineers in 1897. Mr. Walker made a great many experiments, which he quotes at length in his paper, but the ones upon which formula (2) is based were made with two straight-vaned fans, each 23¾ inches in diameter, revolving at a speed of 600 revolutions per minute just inside of a delivery tube 24 inches in diameter. He determined the number of cubic feet of air discharged by each fan when the vanes were set at different angles, and found that both gave the best results when the vanes were set at angles of about 40 or 45 degrees. If we call the diameter of the tube equal to the diameter of the fan, as we may without much error, the area of the tube in square feet is $\frac{3.14\ D^2}{4 \times 144}$, when D is the diameter of the fan in *inches*. The *mean* velocity of the air in the delivery tube is the number of cubic feet of air delivered per minute divided by the area of the tube. That is, if V be the mean

velocity of the air, and C the number of cubic feet of air delivered per minute, we have

$$V = \frac{4 \times 144\ C}{3.14\ D^2} = \frac{183.4\ C}{D^2}.$$

The peripheral velocity, $V_0$, of the fan is

$$V_0 = \frac{3.14\ DN}{12} = \frac{DN}{3.82},$$

where N is the number of revolutions per minute.

From these two equations we find that

$$\frac{V_0}{V} = \frac{D^2N}{3.82 \times 183.4\ C} = \frac{D^2N}{701\ C}.$$

From Walker's experiments I found that when the vanes of the two fans were set at an angle of about 40 or 45 degrees, $\frac{V_0}{V}$ was 4.5 for one and 4.2 for the other. Taking the average of these values we get

$$\frac{V_0}{V} = 4.35 = \frac{D^2N}{701\ C}.$$

From which we have

$$C = \frac{D^2\ N}{4.35 \times 701}$$

$$= \frac{D^2\ N}{3{,}050}.$$

If now we take DN as equal to 21,000 we have

$$C = \frac{21{,}000\ D^2}{3{,}050}$$

$$= 7\ D^2, \text{ about.}$$

From the results of the experiments quoted by Geo. E. Babcock, in the Transactions of the American Society of Mechanical Engineers, Vol. VII, 1886 I find that $\frac{V_0}{V}$ for a Blackman fan is about 2.68. So that for a Blackman fan

$$C = \frac{D^2\ N}{1{,}880}$$

And if, as before, we take DN as equal to 21,000 we have

$$C = \frac{21{,}000\ D^2}{1{,}880}$$

$$= 11\ D^2, \text{ about.}$$

At the meeting at Munich, in August, 1898, of the Heating and Ventilating Specialists, Engineer A. Marx, assistant in the Tech-

nical High School of Berlin, read a paper on Screw Ventilators in which he gave a number of formulas for disk ventilators, with the constants which make the formulas applicable to the ventilators made by two European firms and one English firm.

Among the formulas which he gave is one which, when put into English units and DN taken as equal to 21,000, becomes for the fans made by the Blackman Ventilating Company, London,

$$C = 9.3D^2$$

Where C is the number of cubic feet of air supplied by the fan per minute when working with free exit and entry, and D is the diameter of the fan in inches.

For the fans made by G. Schiele & Co., Frankfurt, a. M., Germany, the formula, when English units are used, becomes

$$C = 9D^2$$

For the fans made by Sulzer Bros., of Winterthur and Ludwigshafen, a. Rh., Germany, two formulas are given: One, for low pressure ventilators, which is

$$C = 8D^2$$

and one, for medium pressure ventilators, which is

$$C = 9D^2$$

Mr. Marx gives a number of other formulas besides those which I have quoted, such as formulas for determining the pressures produced by these ventilators when revolving at different velocities and delivering different quantities of air. But as these formulas are quite complicated, I have not considered it advisable to quote them here.

The formulas which I derived were deduced some time before I received a copy of the paper read by Mr. Marx before that German society which corresponds to the American Society of Heating and Ventilating Engineers. And I present the formulas to this society with the hope that they will be thoroughly criticised, and, if the constants which I have given are not the proper ones to be used, that others will be given by those who may have more knowledge of disk fans than I have. The formulas will, I think, commend themselves to all on account of their simplicity and the ease with which they can be used. While I appreciate that it is more important that a formula should be correct rather than simple, yet I feel that it is almost impossible to obtain a formula that will be rigidly correct for all makes of disk fans, even though the fans may be of the same

general type. And, therefore, I submit my formulas as simply giving fairly close approximate result for straight vaned fans and fans of the Blackman type.

DISCUSSION.

The President: Gentlemen, you have heard the paper. The subject is open for discussion.

Mr. William Kent: Mr. President, I do not know why Prof. Kinealy limits the speed to that which will make the product of the diameter by the revolutions to equal 21,000. He apparently bases it on the limit of strength for a cast-iron flywheel. A revolving disk fan is an entirely different thing from a cast-iron flywheel. I believe most disk fans are made without any cast iron at all but are made of wrought iron and do not have the same dangerous stresses that are set up in flywheel rims. So that it is possible to run them at a much higher speed than we give for flywheel rims. The fan manufacturers' catalogues show a much greater speed than 100 feet a second. I compared the formula of Prof. Kinealy with some figures given by the Buffalo Forge Company for their blowers, and I find that when the number of revolutions are taken such that the diameter multiplied by the number of revolutions equals 21,000 it comes about half way down their table; that is that their figures for average capacity agree very closely with those given by Mr. Kinealy's formula. On the whole I consider Prof. Kinealy's formula a very good one, only subject to the statement that you may get larger capacity by increasing the velocity of the fan, and that when the fan is built of wrought steel, as it should be, it is unnecessary to keep the speed down to the low figure that he gives.

Prof. Carpenter: Mr. President, I have read the paper of Prof. Kinealy with considerable interest and I have adopted the same conclusion which Mr. Kent has stated. I think it will be found that even in disk fans the capacity will vary as the cube of the diameter. In fact that would follow from one of the formulas which Prof. Kinealy gives on page 130 and would also seem to agree with what investigations I have been able to make.

The President: I suppose we are all surprised to find that they agree with the manufacturers' ratings.

Prof. Kinealy: I am, of course, pleased that the formulas I present are so favorably received, and I hope that the members of the Society will find them as convenient and useful as I have.

I limited the peripheral velocity of the fans to 90 feet per second because if it be higher, undue stresses may be set up in the rims;

and because with this velocity, the mean velocity of the air in the delivery tube will be about 21, equal to $\frac{90}{4.35}$ feet per second, or 1,260 feet per minute for straight-vaned fans and about 34, equal to $\frac{90}{2.68}$ feet per second, or 2,040 feet per minute for fans of the Blackman type, velocities which are as high, if not higher than, we should expect to obtain with such fans. Again, I am inclined to think that at higher velocities, fans will "hum" and be noisy.

# LIX.

## TOPICAL DISCUSSIONS.

TOPIC NO. 1.

**The number of air changes per hour which should be allowed for in the different types of buildings.**

The President: To start the discussion in a general way I will say that it is generally assumed that if thirty cubic feet of air per minute per occupant for a building of any class, excepting hospitals or places of that kind, is provided, it is all sufficient. Now is it too much, is it too little, or is it enough, and may it be considered a standard? That is simply to start the discussion.

Prof. Carpenter: I think there has been a great deal said pro and con on this subject, but we have really very little information upon which to base any positive opinion. I think we are limited perhaps by economical considerations more than anything else. I believe no one doubts but that if thirty cubic feet per minute is good forty cubic feet per minute might be better; but whether it would be enough better to warrant the extra cost for introducing it is entirely a different question. It seems to me that possibly some test might be made which would throw some light on this subject, but so far I have not seen anything by means of which I could adopt an opinion. I do not believe that we could adopt any standard to-day which we would be willing to stand by in the light of future investigations a few years hence, and for that reason I have not felt even willing to see any standard adopted by the Society. I think we have recommended that it should not be below a certain point. I think that is a very good place to leave the discussion for the present.

Mr. Jellett: Mr. President, to attempt to formulate any standard for different types of buildings, of course would be a very difficult thing. You take a school room with a fourteen-foot ceiling and one pupil to every four and possibly every five square feet of floor and compare it with a church in which there is a ceiling 75 or 80 feet high and relatively very much larger floor space

because of the chancel and aisle spaces and such other spaces as are given up, there is no basis on which you can average it at all. Now I have been working on church work on the basis of 1,000 cubic feet per hour per occupant. I have found that ample. I have recently completed plans for a church building which has two auditoriums, the first or ground floor and the main floor. Each of these seats 1,500 people, on a level. There are no galleries outside of the choir and organ gallery. But I have to supply 25,000 cubic feet a minute into each of those auditoriums. One had a fourteen-foot ceiling, the other is 82 feet clear. In one place I started in with about 160,000 cubic feet of air space; in the other I have 675,000. Manifestly it is very much more difficult for me to deliver that amount of air into the basement auditorium with a low ceiling without draughts and with a good circulation than in the larger room, because I start in one case with 675,000 cubic feet of fresh air; in the other I start with 160,000. Those conditions are entirely different from what you find in school work. Again you find the sessions very much shorter. The church services will average at the most an hour and a quarter to an hour and a half, and the contamination is not percepitible even though the air was not changed so rapidly, until the time approaching the completion of the service when the people are going out of the building. Take office buildings. You find some rooms that are filled with clerks. The corresponding amount of space in the next room has one man in it, possibly a stenographer. So that it is almost impossible to formulate an average for the different classes of buildings. I think if we could determine that the contamination of the air should not be greater than a certain per cent in all classes of buildings, and then when an engineer is called on to design a ventilating plant for a church building or a school building or an office, or any other kind of a building, that he should take into consideration and figure for the contamination and not for the volume, and he must determine the volume on the conditions of use in the building to be erected. In insane asylums I have put in as much as 3,500 cubic feet per hour per occupant and I found it none too much, but for the same space place occupied by entirely healthy people who were in condition to take care of themselves 2,000 cubic feet of air would have been ample. So that really it is the conditions and not the different types of building that govern your work.

The President: As a matter of information, there was a reason why we began to talk about 30 cubic feet, and it was well founded. In Massachusetts the original requirement was 20. Chief Wade, in

looking into the matter when the law was passed there, went at it I think in a very satisfactory way; and we may profit by his experience. The main object was to maintain in the room a degree of purity of the air that was healthful. He consulted with many eminent authorities, and the general opinion seemed to be that when the inside air was kept within .0006 of the purity of the outside atmosphere, taking the carbonic dioxide as a factor, that to all intents and purposes it was perfectly healthful and fit to breathe. This applies to buildings which come under his department. I suppose it would be correct for the ordinary type of building, except churches and places of that kind where there is a large air space. By experiment it was found that by introducing 20 cubic feet of air per minute he could not maintain that degree of purity. Under the most favorable conditions he could maintain it with 25. In 95 per cent of the conditions they met they could not do it with less than 30, but with the apparatus properly installed and introducing 30 cubic feet of fresh air per occupant per minute there could be that degree of purity maintained at all times, and that was the reason why the standard was made 30 in Massachusetts, and part of the requirement I believe at the present time is that the purity to be maintained shall be within .0006 of carbon dioxide of the purity of the outside air.

The President: The question of ventilation resolves itself into nothing more or less than dilution. When we say that we settle upon a degree of purity, we take carbon dioxide or any other factor that is easy to determine. Of course there is hospital work where you would not think of putting in less than 125 feet for patients and 60 for the nurses. It is a question of dilution and a standard of purity. If we make a standard of purity then we have to figure the amount of fresh air that will so dilute the air in the room to keep it within the given bounds. The volume of air to be supplied to a room per capita depended upon the number of people in the room and upon how long the people were going to remain in it. If you have a very large room and a small number of people who were only going to remain there an hour you might not need to supply any ventilation at all. That is to say that those people would not vitiate the air within the time they occupied it, and he gives a formula by which the amount per capita can be calculated. I will try to put it in the discussion.

TOPIC NO. 2.

**The duty of a heating and ventilating engineer to his client.**

Mr. William Kent: There is only one answer that can be given

to that question. I think the heating and ventilating engineer when called in must put himself in the position of the client and do for the client what he would wish to have done for him if he was the purchaser of the apparatus himself. He should ask himself what would I do if I were the owner of this building? How would I do if I had as much money as my client has? How would I fix this thing? And then he should tell his client that that is the thing to do. If there is any other method I would like to know it.

The President: That is the proper method, Mr. Kent.

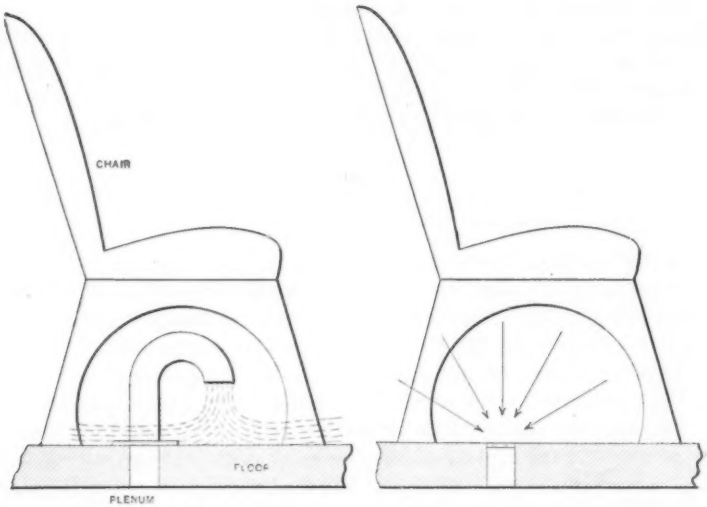
TOPIC NO. 3.

**What are the relative advantages of the upward and downward systems of ventilation for audience halls?**

Mr. William Kent: I do not wish to discuss exactly the type which is the best, the upward or the downward system of ventilation, but I wish to call attention to the advantages of an upward and downward system, combining the two. We have a grand illustration of that combination of the upward and downward system in this room. Here we have the entrance of very hot fresh air at this register and we have very cold outdoor air coming in at the top, and the hot air goes up and the cold air comes down. I think we have had enough demonstration at this session of how bad a system that is. If we let the cold air in it comes down on top of the bald heads and we get cold, and if we do not do it we are roasted by this hot air and the foul air does not get out at all. I hope that before we meet here again next year that the heating and ventilating engineers will do something to heat and ventilate this building properly.

Prof. Carpenter: It seems to me that the question as put is hardly any more discussible than would be the question which is the best system of heating, steam or hot water. That was at one time quite a live topic, I believe, and this no doubt would be a very live topic. Now it is possible to ventilate by either system. Circumstances must very largely govern, and if we could get good ventilation, it does not matter whether it is obtained by down currents of air or by up currents of air; for that reason it seems to me that we ought to express no general opinion. I do not believe we will get any benefit whatever out of a discussion of the question. In the treatises on ventilation there are a great many cases given of both kinds of ventilation. Take Péclet's treatise for instance. There are good reasons adduced by the author why either one might be better under certain conditions. I think we do not need nor had we better go into a discussion of this character.

Mr. Henry C. Meyer, Jr.: Mr. President, I would like to discuss the problem under special conditions. I think the answer depends upon the temperature of the incoming air; at least the air is a controlling factor in the case. What I mean is if the air temperature is below




that temperature at which drafts are felt or at which a person is likely to catch cold, I think the downward system is better for audience halls. A number of audience halls in this country have been ventilated by cutting holes through the floor into a plenum chamber, putting a hood over the top and diffusing the air in this manner. If the air was put in at a low temperature—Mr. Jellett, I think, said he had put it in at 62 degrees—that method is bound to be objectionable on account of the cold draft that is apparent about the feet of persons occupying the chairs. If you draw the air down through a register in the floor the draft is not nearly so great and furthermore the air then moving about the legs of occupants of seats is of the same temperature as that to which their bodies are exposed. There is a reason why the upward system of air supply causes greater drafts and it will be apparent upon examining the accompanying figures. In the first the air is distributed over the floor of the theater by a hooded opening. The high velocity of the incoming air causes it to be projected to the floor and then spread out fanlike as shown, the air current following the floor for some little distance. If, on the other hand,

the air enters a register opening in the floor, as shown in the second figure, the slow moving air currents will gradually converge toward the opening and there will be much less draft apparent. In fact, the air will not attain a sufficient velocity to cause a draft until it is within a very few inches of the register. Then it is harmless. The principal objection to the upward system in audience halls is, however, the fact that as the air has to be supplied at a low temperature, dangerous drafts are experienced, even if the velocity of the air is low.

The President: Is there any member who from his own personal knowledge knows the purely upward system of ventilation in a large assembly hall, State capitol or anything of that kind, that is entirely satisfactory?

Mr. Meyer: The American Theatre in this city has been operated by the upward system. I have never heard any complaints of it.

The President: Have they ever had enough people there to know?

Mr. Meyer: Oh yes, occasionally.

The President: There is a method of course that is being used in a number of theatres where they use a chair with a hollow leg and blow it out that way.

Mr. Meyer: That is put in by Prof. Woodbridge in the United States Senate. The air supply comes up through the hollow legs and is diffused, but in that plant the air is throttled before it enters those legs so that it passes out at a comparatively low velocity. I believe that Prof. Woodbridge could not do anything else on account of the conditions that he found when he took hold of the work.

Mr. Jellett: I can name one case of that kind, the operating amphitheatre to the Medical Hospital in Philadelphia. The ceiling is 52 feet high. The entire ventilation is from the ceiling. There are some twelve registers averaging I think about 24 by 30 inches in the ceiling. There is no other exhaust in that room, but the air is brought in in a series of cast iron necks distributed under the seats and the tiers in the pit. There are 135 points of delivery of air in that room. The men sit on inclines around an oval-shaped pit in the base of which is the operating table. To attempt to pull the air out from the sides would bring draughts in the faces of the students. To attempt to pull it out from below would interfere with the use of the pit because they must flush it after operations with a disinfecting fluid, so that the entire floor is washed and any

openings of any kind would create trouble. But the cone shaped deliveries have curved tops and are so distributed underneath that the water cannot get into them. In that room I have made tests during operations, with thermometers placed in the operating pit 12 inches from the floor and thermometers placed 12 inches below the ceiling, and I have had continuous tests with readings every five minutes during the lecture which lasted one hour and twenty minutes, and the temperature has varied only 1½ degrees and I have held that room under these conditions with a variation of one degree. The air comes in from 135 points and the movement is gradual. Above there is no fan, but there is an aspirating coil. The delivery fan below is very large so that the volume of air given to the room is something like 32,000 cubic feet per minute at a velocity not exceeding 300 feet at any one point. The doctors there say they have never felt any draughts from it. They have been entirely satisfied. It has been in use two years. But that is the only example that I know of where the out takes are all in the ceiling.

The President: I would ask Prof. Carpenter, as a matter of information, if the downward system is not considered preferable for the reason that in breathing we naturally breathe downward. Now if the current is down that is naturally carried away. If it is upward, as we inhale again and the air comes up to us, do we not inhale more impure air than we would by the downward system?

Prof. Carpenter: I remember in Péclet's treatise on heat, which I think has not been translated, there is an admirable summing up of the advantages and disadvantages of these two systems. With your permission I may state in a very few words the results of his conclusions, which are: That the upward system of ventilation would be preferable when the conditions were such that the air could be introduced practically over the whole area of the floor and could be taken out practically over the whole area of the ceiling and conveyed through the room at a very low velocity. The downward system would be preferable when the air had to be introduced at a limited number of points or taken out at a limited number of points; the reasons for these conclusions being that when we can introduce the air over a very large area we utilize the natural force of gravity (due to the fact that our inside air is almost always lighter than the outside air) to assist in ventilation. Consequently, the conditions being as I have said and everything else being equal, the upward ventilation is preferable, practically, however, downward ventilation is in his opinion very much better because those conditions which I have mentioned never exist; as air must be supplied at

a limited number of points, and moreover, it is almost impossible to arrange the floor so that dirt and debris from the feet will not fall into the fresh air ducts in which case there is a great deal of danger of contamination of the air. Now so far as the effect of breathing is concerned, the gas which is exhaled from the lungs contains a good deal of watery vapor. It contains of course some carbonic acid gas, and when it is first exhaled it has about the temperature of the human body. That temperature is sufficient to make it rise at first very slightly about the head until it cools. After it cools there is a tendency for the watery vapor to condense. It depends on conditions of course whether it would all condense or not, but there is a tendency for it to condense, and there is also a tendency for the carbonic acid to fall provided it is not intimately mixed with the surrounding air. Hence it would seem that the natural outlet for the foul gases should be downward, although on account of the wonderful power of air to mix or diffuse intimately with all the gases of respiration I presume this difference is not a very marked one. I thought the statement of Péclet in regard to the various methods of ventilation a fair one as it gives consideration to both methods.

Mr. Henry C. Meyer, Jr.: Following Mr. Jellett's remarks I would like to state that if any New York member wants to examine the type of system which he describes, there is one in the Sims Clinic which is attached to Roosevelt Hospital at Fifty-ninth Street and Ninth Avenue in this city. In the main, I think it is the same as that in Philadelphia, isn't it, Mr. Jellett?

Mr. Jellett: It is practically the same; but the delivery varies. In Philadelphia they deliver at a great many more points.

TOPIC NO. 4.

**Would it not be in the interest of the purchaser to rate radiators by their heating value based on certain standard conditions?**

Mr. Jellett: For the information of the members I would say that the topic was sent in by Mr. Eisert who hoped at the time he sent it to be here to discuss it, but on account of the rush of work at the Government office at Washington he could not get leave of absence.

Prof. Carpenter: I would say that Prof. M. E. Cooley of Michigan who has tested a good many radiators has always held to the affirmative of the question; that is he thinks that radiators should be rated not by actual measurement but on the trade measurement, and that their heating value should be expressed in those terms,

which is essentially the method proposed, i. e., of rating a radiator by the amount of heat it will give forth instead of by its size or shape. It seems to me however that the idea is not a practicable one. I do not doubt it would be an excellent plan provided it could be carried out. But how can a man tell if he cannot make a test of the value of a radiator? You can measure a radiator. Now I should say from the experiments that have been made on radiators that radiators of certain types and dimensions constructed in certain ways with certain air spaces around them, and of a certain height, have about the same value per square foot of actual surface and those values are pretty well known. It seems to me that if we buy radiators by their actual surface and then judge from what data we have in regard to shape, that we have now all the information we can possibly get in regard to rating them. I think in practice that it would be a very difficult thing to rate them by the amount of heat that they would give off.

The President: The purchaser has very little to rely upon except the guarantee given him by the contractor and he depends of course upon the manufacturer. Mr. Fowler, have you anything to say regarding this question?

Mr. Fowler: I think this question might be worthy of a committee to thoroughly investigate and go into the subject for a year. Perhaps some information could be brought out that would be of use to engineers in designing that might save weights in building and first cost of installation. I would not offer that as a motion but I will offer it as a suggestion.

The President: I do not see exactly how that could be arrived at under the direct title of this discussion here: "Would it not be in the interest of the purchaser to rate radiators by their heating value based on certain standard conditions?" Under that topic or title it would probably be referred I should imagine to the committee on tests or the committee on standards with the request that they report at the semi-annual meeting. You were not present yesterday and the day before, and there have been several papers ordered printed, to be submitted at our semi-annual meeting, and a motion that this be referred to that committee or the incoming committee on either standards or tests, with the request that they report to the semi-annual meeting, would be a proper motion.

Prof. Carpenter: In connection with the question there is one point which I presume was in Mr. Eisert's mind when the question was put which might be worthy of a minute's consideration, and that is the fact that in a great many of the radiators there is an

immense amount of cast iron wasted, and despite all that has been said and talked about the best proportion of radiators the manufacturers pay no attention to it and the purchasers pay no attention to it and they go on using about 25 to 30 per cent more cast iron than is necessary. Possibly this is true because they cannot very well do otherwise on account of the demands for certain forms. I think attention has been called, not only by tests that I have made and read before the Society, but by tests that other engineers have made, to the fact that a low radiator is much more efficient per unit of surface than a high one. A twenty-four-inch radiator on our tests gave off nearly as much heat as one with the same form of loop 38 inches high. This result has been checked by numerous tests. A thin radiator is much more efficient than a thick one, yet most radiators are very thick and this cuts down the heating effect enormously. The heating effect of a loop is very much more where it is exposed freely to the air, a single loop of radiator. Now these principles are often overlooked by manufacturers and by users, and the result is that the amount of cast iron which is put in the buildings is far greater than there is any need of.

The President: I think, gentlemen, that with this fact presented to us we most certainly ought to refer the subject to our committee and have them make a report. Naturally in figuring direct radiation we figure the number of feet of radiation required. Now if we get as much, or if all is wasted above say 24 or 26 inches and we buy so many feet of radiation or specify so many feet of radiation to heat a given amount of air, here you have it explained why it does not do it, and the quicker we are set right on it by engineers the better it will be for all of us. I hope that the matter may be referred by motion to a committee and the committee be requested to act. The Committee on Standards I assume would be the proper committee.

Mr. Fowler: Mr. President, I have been giving this subject a good deal of study within the last year or two. I do not want to say anything here that would be taken as any effort on my part to advance any idea that would benefit myself, but I believe that the standard of measurement for radiators should be governed by the amount of air that is exposed on both sides of the radiator instead of the number of square feet of radiation clustered together and while I have not collected any data on the subject that I could present to-day I believe that the subject is a fertile field for investigation and I believe that results that would be quite astonishing could be obtained by a committee who went to work on that subject.

The President: I presume you have more or less data that you could give to the committee so far as your investigations have gone in this matter?

Mr. Fowler: We find in actual practice that there is a great saving accomplished, that is in the number of square feet of surface required, by spreading out the radiator in a large exposure, and some steamfitters who have had quite a successful season's business have been using with that type of radiator about 25 to 30 per cent less than they would have used with a radiator clustered up together. That is actually demonstrated and can be proven and is in daily operation to-day in a large number of cases.

The President: I think that we had better leave this to our committee and if a motion be made that it be referred to that committee and include in the motion that the members who are conversant upon this subject of radiation particularly give to the committee such information as they can.

Prof. Carpenter: I move that it be referred to the Committee on Standards.

The motion was carried.

TOPIC NO. 5.

**Are the capacities of steam traps as given in makers' catalogues of any practical value to the engineer?**

Mr. Jellett: Mr. President, I hope this subject will be discussed, because my experience has been that the tables of capacities published are of no practical value. The average manufacturer of traps when he gives you a table at all states that No. 1 or 2 as the case may be will drain 10,000 lineal feet of one-inch pipe. It does not make any difference what work the pipe is doing or the amount of steam it is condensing. Tables that give such information are absolutely useless, because the condition governing the use of a steam trap has everything to do with it. If you take 10,000 feet of one-inch pipe and use it for heating a building in the usual form of wall coils, there is a certain amount of condensation for the trap to control. If you take the same 10,000 feet and put it into a fan coil you will find you have quite a different problem for that steam trap, so that the data are absolutely misleading. They are not only of no practical value, but absolutely misleading to the man who pretends to pay any attention to it. I think other members here have had the same experience, and I would like them to give us some information on this question.

Mr. Paul: A number of years ago I had something to do with

handling traps. I have not handled them lately. I realized that point that has been made and the former catalogues all said so many thousand feet they would handle. But in the later catalogues that were issued it said so many gallons of water, and I think if you find that catalogue you will find so many gallons of water added to so many thousand feet of surface; so that they both are in.

The President: Mr. Gormly, what is your experience in the matter?

Mr. Gormly: Well, I find that traps vary in their capacities; that is the ratings of traps cannot be followed, and we have had some little difficulty in that, but my principal work is the kind in which we do not use very many traps so that I have not had very much difficulty in that way.

The President: Mr. Joslin, what is your experience in this direction?

Mr. Joslin: Mr. President, I have not had much experience in manufacturing, only for a short time. I have had experience in using them, and I only followed the custom, and I think the custom wrong, as Mr. Jellett has said, and I hope that it will be thoroughly discussed so that possibly the manufacturers can change their catalogue or at any rate not put anything down; let the steamfitter decide for himself by the size of the opening; something of that sort; unless they can get at some means of determining what the trap will do. Of course different forms of traps with the same connections will do different work.

Mr. Paul: I might make one further remark in regard to traps. Of course this covers steam traps of any description. Now I have had an experience within a short time in which a steam trap would not deliver anything for the reason that it was a temperature trap, and the consequence was it connected against a sealed return, and the sealed return kept the temperature up, so that it could not deliver anything. It was not a question of what there was on the other side of it. Therefore the condition under which they are connected up has something to do with it.

Mr. Mackay: My opinion is that the ratings of traps were made before many of them were used in connection with fans, in fact before fans were used in heating and ventilating buildings to any great extent, that the rating was based on the amount of direct radiation which was in lineal feet of one-inch pipe, and that the later manufacturers of traps have manufactured them of the same capacity, and consequently gave them the same rating. The rating is right if you consider it in the way it was originally intended, but

wrong if you attempt to consider that it is to be used in the fan system instead of direct radiation in the room. Traps were formerly largely used in connection with the heating of factory buildings where the radiation was one-inch pipe on the outside wall below the windows, and it is merely a mistake in not carrying out the ratings further. It is misleading where a man who is a novice at the business takes hold of a manufacturer's catalogue and because he has got 10,000 feet of one-inch pipe thinks that a trap rated at that capacity will take care of it. An intelligent and experienced engineer would not make that mistake. I think of that as I said of radiating surface this morning, that an intelligent engineer would not make that mistake, and that all such engineers have a value for the radiating surface regardless of anything that the manufacturer may publish as a commercial rating. I think that the same thing will apply to this trap business, that the men who are largely using traps know what they will do.

The President: In other words, you think the rating is proper for direct radiation and the engineer must use his judgment for indirect radiation and for the fan system.

Mr. Mackay: I think it would be wise for any one using traps to use them inside the manufacturer's ratings for direct radiation and put a proportionately reduced rating on when used for direct-indirect, or the fan system.

Mr. Jellett: I do not agree with Mr. Mackay as to the basis of the ratings. I think the rating of the trap was made before the pattern was completed. I have found in some cases that was the case. When a new trap was manufactured the schedule was made on the size of the openings to go about 10 per cent better than the other maker's traps. I think there was no basis whatever outside of that.

Mr. Mackay: This trap business had a starting point with the first trap used. It may be, as Mr. Jellett has said, that each man as he manufactures traps wants to sell and he has got to have some selling point and he makes 10 per cent more capacity than the other fellow.

Mr. Connolly: While we are talking on this, why not take up the rating of automatic pumps and receivers. They bear the same relation. I would like to hear Mr. Jellett on that.

Mr. Jellett: I do not think it would come under the same heading.

Mr. Connolly: Well, they are rated, and I would like to know if they are overrated from your experience.

The President: Mr. Harvey, can you give us any information on the topic?

Mr. Harvey: I do not think that I can give you any practical information that every man who has had any experience has not already had in that respect. Of course we have sometimes had occasion where the trap was rather small to take out the valve that was in it, and put in a larger one if the pressure was not very great on the discharge—on the return pipe. We have just made a little larger opening, a larger valve ourselves. But as a general thing traps have proved in my experience to be pretty near up to their rating. I never found any difficulty that way.

TOPIC NO. 6.

**What rules are usually followed for proportioning direct-indirect radiation and how many heat units are given off per square foot of heating surface per hour under ordinary conditions with this system?**

The President: I should say probably it depends on which way the wind blows.

Mr. Meyer: I think it does.

The President: That is about all there is of it.

Mr. Billings: Mr. Paul must have some data on that.

The President: We would be glad to hear from Mr. Paul.

Mr. Paul: What data do you want me to give?

Mr. Billings: Those tests in your office.

Mr. Paul: I understand now what he means. There was a test made on the question of putting a box around the radiator, and allowing the natural current of air passing up over the radiator, finding out the number of heat units that were delivered per hour; but it does not seem to me that it covers the case. I think the experience that some have had with that system was not satisfactory, that is to say that some buildings that have been fitted out that way have not continued to use it. Mr. Jellett might tell us his experience in the matter.

Mr. Jellett: I have put in a great deal of direct-indirect heating, and still do. I have not any trouble from it from the fact that it won't heat, or anything of that sort. I think the mistake made sometimes is to attempt to control the air inlet automatically, or to control the valves on the radiator automatically, and leave the air inlet without any control. There is where the trouble comes in. I have seen such a combination, but I have never put in one of that kind and do not intend to. So far as direct-indirect

heating is concerned, I think that one of the first buildings using direct-indirect heating that I had anything to do with was about twelve years ago. The air openings then were very much smaller than now. They were about the size of a brick. At that time there were but few forms of radiators other than Nason or Bundy, or similar type with closed base, and therefore the air delivered right across the tubes of the radiator and was not satisfactory. But since we have the open base forms of radiators we have had very much better results. The forms of box-base radiators that are made to-day work out very satisfactorily. I did put in a system for Dr. Billings some eight or nine years ago in the Laboratory of Hygiene, University of Pennsylvania, where he wanted this laboratory fitted out in such a way that he could conduct a series of experiments, and this building has the largest air openings of any system that I know of. I have radiators there that have about 72 square feet of heating surface, and I have two square feet of opening for air, which is abnormal, as judged by the usual proportions. But Dr. Billings wanted air and he wanted a given amount of air moved. After I had gone into it pretty carefully I said, "Doctor, I can give you the air, but you cannot use it." "Why not?" he asked. "Because," I said, "the temperature of the room will be about 90. I will have to put in such an amount of heating surface to pull the air that will be out of all proportion." He said, "I want the air delivered for experimental purposes, and I want to screen the air through raw cotton." The radiators were encased their full height, the wooden casing lined with tin and asbestos, and the air was brought into the base under the radiators. In one room there were nine different styles of radiators used. The cotton was carried between two wire screens of very large mesh set in frames right over the radiators, and in order to get the amount of air through that cotton I had to put in surface in order to furnish sufficient motive power. I saw Dr. Abbott, who is now director of the laboratory, only about three months ago, and he admitted that at no time could he put more than four radiators out of the nine on in the room without opening the windows—the heat was unbearable, but that he was conducting his experiments by using two or three radiators at a time instead of nine. A number of other buildings have adopted this system. But they do not put the air box opposite the box base. In nearly every system I know of the air inlet is put directly below the window sill, so as to get the benefit of a falling column of cold air to start the column in the radiator. There is another building I know of where the arrangement has been changed somewhat from

the usual form, in which the air is taken from the heads of the windows of the story below. The arch of the window head is made of terra cotta and a slot is left back of the terra cotta of about two inches. The air is drawn up through this slot so that the radiator lifts its air supply. That prevents any possibility of rain or anything being driven in, and it also avoids marring the appearance of the building by the openings of the outer wall. It is novel in this respect. The City Hall, of Richmond, Virginia, is built of granite, and the window sills overhang, I should say, three inches. There is a slot for air carried direct below the sill in the granite without any screens at all. The slot is 1½ inch in height and the width of the windows, which would give about 90 square inches of inlet. The shadow cast by the projection of the window sill conceals the opening viewed from outside. You get the air without detracting from the appearance of the building. There have been a number of these devices to admit air. As to proportion I personally do not give more than 10 to 15 per cent. greater radiation, depending on the exposed positions of the bulidings over direct; but I have never taken any series of tests to determine the amount of heat units condensed, and have accomplished the results, giving air with not to exceed 15 per cent. excess surface in any case. I always use a flue type of radiator that I can bring the air through. That touches the question that we discussed this morning of the heights of radiators. I think three years ago when we were discussing that here, I brought up the question of the temperature of the air leaving these direct-indirect radiators. A test showed me with a 24 inch radiator used in this way with three pounds of steam pressure on the main that at a distance six inches above the radiator I got 164 degrees. When I took the same steam pressure and put the radiator thirty-seven inches high I got 167 degrees. So that I remember distinctly making the point at that time that there was no special advantage in using high radiators in this way. You could get better results with low radiators than with high—that is, in proportion to their cost.

The President: Is there anything further to be said on this subject?

Mr. Meyer: I would like to ask Mr. Jellett how he protects the thermomoter?

Mr. Jellett: I simply suspended the thermometers over the flues, not over the iron. It was in the air column. I also put it down in the flue of the radiator itself; that is, between the flues half way down, taking a series of readings there. I got the temperature

then up to 193 and 194. There I had the direct radiant effect of the two flues plus a moving column of air; and where my temperature of steam was 220 I got 193 inside the flues, but not when I suspended three inches clear of the radiator.

TOPIC NO. 7.

**General principles to be observed in the installation of the blower system of heating and ventilation.**

Mr. Davidson: I would say that I have not found two cases alike in my experience, covering nearly twenty years. I could not give any set rule to go by. Everything has to be according to the place in which it is to be installed, the shape of the building and the location, etc.

The President: Condensing that, it simply means the ability of the engineer for the arrangement as to its success, is that it?

Mr. Davidson: That is where it is.

Mr. Jellett: I think that position is correct. But there are also a number of essential things that go with a good design of a system of that kind. One which is very often missed, for want of a little attention, is the question of proportioning and proper installation of a blower system, and it seems to me one that can be determined very largely. The great difficulty that I found in blower systems, in buying standard apparatus, is that they put up a given amount of heating surface for a given sized base without reference to the amount of air that has to pass through it, and your great trouble would be in purchasing a standard apparatus; not that you do not get heating surface enough, but to get clearance enough. In all specifications which I draw I always ask for a given amount of clearance between and around the pipes in addition to specifying the amount of surface, because the clearance is, in my mind, just as important as the heating surface. I have been called in in a number of cases where systems have failed to do their work, and I have found in most cases the principal cause of the trouble was, not the capacity of the fan, but from the fact that the fan could not get its normal air supply, due to the enormous friction through the coil. I have in mind now one particular case. The blower was, I think, 140 inch; had an inlet about five feet in diameter, which would give nineteen square feet. The coil base was four feet long and the coils were seven feet high, a total of twenty-eight square feet; but the pipes were placed so close that there was not over eight square feet absolute clearance. With the enormous friction of the coil—

about thirty pipes in depth—it was impossible for the blower to give its normal air supply under these conditions. The contractor for the work simply said that he had complied with the contract, as he thought, and delivered a heater which contained so many square feet of heating surface. The architect referred him to his specification, which required that he was bound to heat that building and deliver a certain amount of air in it. He said that he had bought what was a commercial apparatus, and that was all he could do. He did not know how to fix it; he admitted that. I told him to take the particular heater and take off four sections from the back of it, and put them at the side of the other sections, and add two more so as to give him the depth required to warm his air to the extent that was necessary and draw through the double width of the heater that he had before. He did that and there was no more trouble. Frequently when contractors send to blower manufacturers for heating apparatus they simply say, "We want a blower of a certain size, and we want the heater to contain so many lineal feet of 1 inch pipe. The blower manufacturer, not being familiar with the conditions, sends him the form of heater that will comply with that request that will cost him the least money. That he is perfectly justified in doing, as he has absolutely no information to base his proportions on. I think the first essential is always that your blower shall be big enough to deliver the given quantity of air through the registers at a fixed speed, and that speed ought always to be determined in the specifications, that the velocity of air should not exceed a certain number of feet per minute. Second, that your heater outside of your blower should have an excess of clearance in actual inches of area over the inlet of your fan. And third, that there should be not less than twenty pipes in depth for the air to pass over, if you are to maintain a temperature of 70° in your building under conditions of zero outside. Fourth, that the area of the discharge from your coil bases should be approximately the size of your feeds if you are working with atmospheric pressure of one pound pressure. A great many fan heaters to-day can condense more water than their discharge openings will deliver at that pressure. I have taken many such heaters and simply bored out the return connections and increased the efficiency very considerably.

These, to my mind, are some of the essential conditions as far as the heater and the blower itself are concerned.

The next point is the question of delivery from your fan to your flues. Now frequently you will find that engineers designing the piping system cut it up into small branches. Wherever it is prac-

ticable at all it is better to shorten your small branches and carry your main trunks as large as will deliver your air so as to reduce that friction. Another point that I consider necessary in this method of heating is that the air ducts should be covered. I have in mind one building where a heater is located at nearly one end of the building. My delivery duct is 328 to 330 feet long. The basement of the building is not used for any special purpose, and the absolute loss between the first flue, after leaving the mouth of the heater, which is some fifteen feet from the discharge, and the last flue on the line, which is some 328 to 330 feet away, varied between 30 and 35 degrees before that pipe was covered. It is the basement of a large dormitory building in a college. They have no use for that basement whatever, and there is a very large amount of air space cooling the surface of the hot air ducts. Now, by properly wrapping the pipe that loss was reduced to about 12 degrees, and that makes a very large return indeed on the cost of the covering when you consider the conditions. So that in nearly all work where it is permissible at all I have insisted on covering the galvanized ducts, and I think that it is the only practical solution of the heat losses where you have to deliver over long areas. I remember one particular system that I had in a mill. I had to deliver air through a total of some 1,300 lineal feet of ducts from one central point—not in one direct line, but branches on different floors, and every floor had to be run horizontally, independent of every other floor. In that particular case I did not cover the ducts because the radiation was in the room that I wished to heat. But it made a very marked difference on the delivery at the end of the line. It explained to some extent the great discrepancy in the figures. I have asked a number of blower men what the effect was on a blower in delivery capacity of the increased weight of the air due to a lowering of its temperature at the long end of the line. I have never found one yet who has made any tests or could give me any data. I think that is a subject that is well worth studying. You start at your fan with a temperature of 165 to 170 degrees. You lose 30 degrees on the line, and your air has become heavier by that decrease in temperature. At the same time your pressure has been decreased very considerably, due to friction, so that there are two things working against you—loss of pressure and increased weight of air. These two things, as far as I know, have never been considered by blower men in that particular connection. Again, you will find that the usual tables on losses in transmission by friction will hold good, practically so, up to a certain point. Beyond

that they are absolutely useless. I have taken the maker's tables, the proportions and the losses in transmission, the frictional losses, and worked it out pretty carefully and found they averaged reasonably well up to lengths of 250 feet. But apply those same tables to lines 350 to 400 feet and they are wide of the mark. I asked one man the cause of that, and he said, "We never have tested for such length of lines. We did not think at the time we made these tables of any such conditions." But they do exist to-day. We have frequently to blow 400 or 500 feet. If you follow such tables, knowing that they are approximately correct to 200 feet, and assume that they are approximately correct at 400 feet, you will find yourself badly mistaken. So I think that the essential things, apart from what I have referred to of the heater and the blower, are the covering of the ducts and the keeping of your main duct of ample size and shortening the smaller branches as much as possible. Try to keep to the one main trunk line, if you have the room, and shorten up the branches.

A Member: How did you cover the pipes?

Mr. Jellett: In two or three cases I have used three thicknesses of asbestos paper. In other cases I have used the corrugated asbestos air-cell covering, which comes in sheets. In one case I used a plastic covering. I will never use it again. It is difficult to keep it in shape, and you never can get a nice looking piece of work with it, and the duct is always liable, in a basement of a building, to have somebody strike against it with something and break it, and the result is that it not only does that but it bends your duct, so that either of these coverings—asbestos paper with two or three wrappings, then covered with canvas and the joint pasted and seamed, or take the air-cell covering. I have just finished an office building in New York city with a double blower system. It has a hot air duct and a tempered air duct, and a mixing damper into each room, driven by a direct connected electric motor. It is rather a novel application of the blower system, and was designed by Mr. Alfred R. Wolff. The building is just being completed now. The system is in operation. It is Nos. 27 and 29 Beaver street, the American Cotton Oil Company's office building. In that arrangement you can deliver hot air or tempered air into any particular office in the building. Those ducts are covered with one inch covering of the asbestos air-cell covering, and there is the same covering between the hot air and the tempered air duct, so that the high temperature of the one might not affect the temperature of the other, and then the whole thing is covered with canvas neatly

put on, drawn and painted, so that the ducts do not look unsightly. They pass through the basement offices and look all right. But that simply means protecting and carrying your hot air to the point of distribution. I think there are others here who have had experience with blower work. I would like to hear from them.

Mr. B. Harold Carpenter: Mr. Jellett speaks of running his ducts out from the fan. I would like to ask if he can give us an idea of the speed that he carries through both heater and fan and before entering the rising ducts. I find that manufacturers differ quite a good deal in this; some say that the ducts should be large enough so that the speed should be over 800; others say that they get better results from 1,500 to 2,000.

Mr. Jellett: My main ducts vary with the conditions. I have never gone over 2,000 feet velocity in the main duct except in factory heating. In factory heating there is no objection to it at all. But in school buildings, churches, and buildings of that kind, I find it is not desirable on account of the humming sounds due to the vibrating of ducts and things of that kind to go beyond 2,000 feet. In a great many cases I have limited them to 1,200 feet velocity in the main to 600 in the rising flue, and 300 in the register.

Mr. B. Harold Carpenter: About 1,200 at the mouth of the fan?

Mr. Jellett: That is the minimum, and in a great many cases I have run up to 2,000.

Mr. Paul: I have had just a little experience on the question that Mr. Jellett brings up of water in the base of the heater. With 15 pounds pressure the heater would cool and the heater was formerly running at 45 pounds pressure, but in reducing the pressure to 15 pounds the heater would commence to cool on account of the water flooding the base of the heater. But my experience has been that the size of supplies has something to do with it. This heater is now working satisfactorily at the atmosphere and is supplied by exhaust steam without back pressure and saving for the owner two tons of coal per day.

### TOPIC NO. 8.

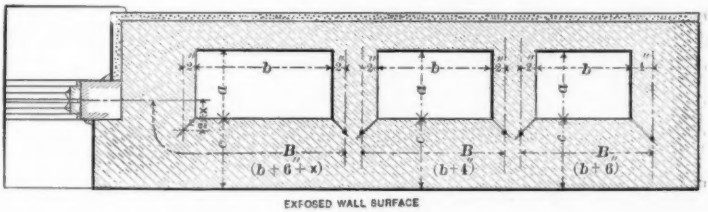
**What is the practical experience as to the loss of heat from hot-air flues, especially when such must be located in outer walls?**

Mr. Jellett: Mr. President, Mr. Eisert sent a written discussion on this topic, together with some tables. I have given it to Mr. Meyer to study it up. He is at work on it now.

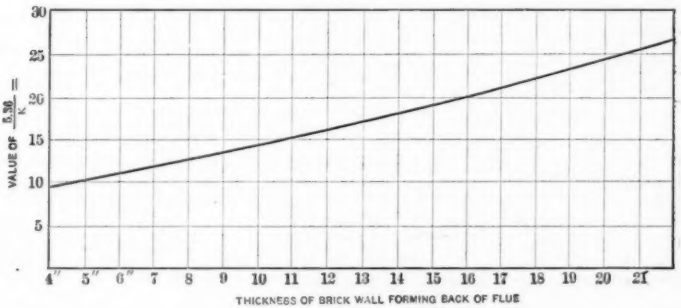
Mr. Meyer read the following written discussion contributed by Mr. Eisert:

THE LOSS OF HEAT FROM HOT AIR DUCTS.

With much interest I have read Professor Kinealy's article on "The Fall of Temperature in Hot Air Ducts," as published in the December issue of "Heating and Ventilation." Concurring with




Professor Kinealy as to the importance of the subject, which is really greater than it is generally conceded, I also have given it some consideration, and came to the same conclusions, though in a different form. Personally I prefer to introduce into the necessary formulæ such data which refer directly to the dimensions of the ducts and to




the pertaining conditions as the best means for obtaining the proper control of the calculation. So, for instance, I determine the fall of temperature in horizontal rectangular hot-air ducts by the expression:

$$t_1 - t_2 = \frac{t_1 - t_0}{\frac{1}{\frac{3}{8} k \left(\frac{1}{a} + \frac{1}{b}\right)} \frac{v}{l} + \frac{1}{2}}$$

which is derived from the equation:

$$\frac{25.\ a.\ b.\ v}{56}(t_1 - t_2) = k\,\frac{2\,(a+b)}{12}\,l\left[t_1 - t_0 - \frac{t_1 - t_2}{2}\right]$$

and that in horizontal round ducts by:

$$t_1 - t_2 = \frac{t_1 - t_0}{\frac{1}{3/4\ k}\,d\,\frac{v}{l} + \frac{1}{2}}$$

which is derived from:

$$\frac{25.\ d.^2\pi.\ v}{56}(t_1 - t_2) = k\,\frac{d\pi}{12}\,l\left[t_1 - t_0 - \frac{t_1 - t_2}{2}\right]$$

when $t_0$ = temperature of air surrounding duct.
$t_1$ = " " entering "
$t_2$ = " " leaving "
l = length of duct in feet.
a = depth " " inches.
b = width " " "
d = diameter " " "
v = velocity of air in duct in feet per second.

Thus with $k = 0.9$ for uncovered galvanized iron ducts and $k = 0.24$ to $0.30$ for such covered with asbestos paper and hair felt in the usual style, not less than 1 inch thick, the fall of temperature $t_1 - t_2$ in horizontal ducts amounts to:

| | rectangular ducts. | round ducts. |
|---|---|---|
| uncovered. | $\dfrac{t_1 - t_0}{\frac{3}{\frac{1}{a}+\frac{1}{b}} \cdot \frac{v}{l} + \frac{1}{2}}$ | $\dfrac{t_1 - t_0}{1.5\,d.\,\frac{v}{l} + \frac{1}{2}}$ |
| covered. | $\dfrac{t_1 - t_0}{\frac{11}{\frac{1}{a}+\frac{1}{b}} \cdot \frac{v}{l} + \frac{1}{2}}$ | $\dfrac{t_1 - t_0}{5.5\,d.\,\frac{v}{l} + \frac{1}{2}}$ |

Of course, for other covering material the value k must be changed accordingly. As to the loss of heat from vertical flues located in outer walls, the conditions are somewhat more difficult. However,

for such cases I have found that the following expression will answer for all practical purposes, viz.:

$$t_1 - t_2 = \frac{t_1 - t_0}{\frac{5.36}{k} \cdot a. \frac{b}{B} \cdot \frac{v}{l} \cdot \frac{1}{1+p} + \frac{1}{2}}$$

which is derived from the equation:

$$\frac{25. a. b. v}{56} (t_1 - t_2) = k \frac{B}{12} l \quad (1 + p) \left[ t_1 - t_0 - \frac{t_1 - t_2}{2} \right]$$

When B equals a dimension (in inches) representing the width of the exposed surface of the flue measured in centre of wall forming back of flue, as indicated in sketch; $t_0 =$ temperature of atmosphere outside; $p =$ an allowance for the exposure of the flue backing to wind and weather and to point of compass (usually $p = 0$ for southern exposure well protected to $p = 15$ and more for north and northwestern exposure); a, b, v, l to $t_1$ and $t_2$ denote the same as before.

By reason of the higher conductive power of stone it is advisable to make some allowance to that effect whenever brick walls are faced with stone. For all practical purposes it will suffice to assume that the conductive power of a brick wall with an alternate stone facing of 4″ and 8″, 6″ and 10″ or 8″ and 12″ thickness, is equivalent to that of a plain brick wall, 2″, 3″ or 4″ less in thickness.

The practical application of the formula for the loss of heat in vertical flues is not so complicated as it appears upon a first glance. The value $\frac{5.36}{k}$ can be computed for various thicknesses of the brick flue backing and the results averaged in the form of a diagram as shown in Fig. 2. Furthermore, as it can be safely assumed that the value $\frac{v}{l}$ is a constant for each story, the product $\frac{5.36}{k} a \frac{v}{l}$ is a constant for all flues of the same depth (a) in the same story. The only variables are the values $\frac{1}{B}$ and $\frac{1}{1+p}$, which represent the varying conditions that have to be considered as such for each case.

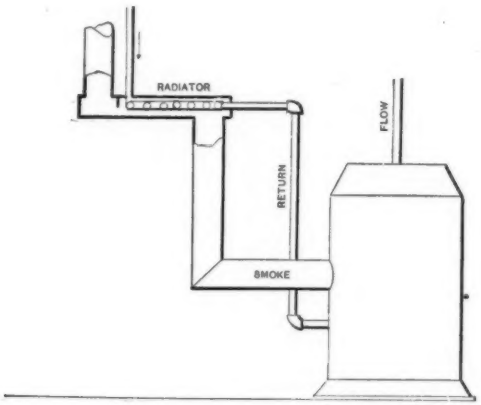
H. EISERT.

Baltimore, Md., January 22, '99.

TOPIC NO. 9.

**Simple, inexpensive schemes for warming and ventilating small buildings (dwellings, etc.)**

Prof. Carpenter: This is a topic about which we perhaps could talk a good while. During the last year I put in a sort of economizer arrangement in connection with a furnace in a small residence that has worked very well and has succeeded in reducing the coal bill one-third on the hot air furnace when it was employed. The furnace in question was one of the kind that utilized probably about 30 or 40 per cent. of the heat in the coal and the greater portion of the remainder went up the chimney; the principal question was how we could reduce that chimney loss and utilize it in heating the build-




ing. I added first a hot water heating attachment, made by putting in one of those small hot water pots built by the maker to go in the furnace, and radiators on it, but still the chimney losses continued. I then arranged a radiator right in the downward circulation of the water and placed it in a special smoke pipe between the chimney and the furnace in such a manner that the waste gases from the furnace passed over that radiator. The down circulation of hot water current came through the radiator and the hot air and smoke outside it. The special smoke pipe was a sheet iron case so made that it fitted closely over the radiator and so arranged that the radiator came very close to the top, so that the smoke from the furnace passed underneath the radiator, and a small diaphragm placed near

the discharge end deflected it down to the bottom as it went out into the chimney. The construction was quite inexpensive, and I might say that it has been an entire success. It is nothing more or less than an application of the economizer to a small house heating job. The chimney temperatures, which have before been run up to about 400, sometimes as high as 500 degrees, have now kept under 200 all the time, and still we have had plenty of draft. It is a very simple, inexpensive scheme, which has resulted in making the furnace a very efficient means of heating. This was accomplished by picking up the waste heat which was going up the chimney and using it to help warm water in the circulation.

Mr. B. Harold Carpenter: I would like to ask Professor Carpenter if his furnace was sufficiently large for doing the work without heating his flues up to 400 or 500 degrees, keeping it at a moderate rate, and could he have used this same design with a larger pressure in moderate weather? Would this check the draft arrangement so that you would have to burn a harder fire to get the draft to carry it off?

Prof. Carpenter: The question is, whether the cooling of the flue would affect the draft very seriously. That question has been decided experimentally by the manufacturers of economizers for steam plants. A very great many economizers have been built and located in various positions in connection with power plants. They do reduce the flue temperature very much. They also reduce the draft very slightly. But in no case that I can learn of have they ever lacked for draft. The manager of the Green Economizer Company told me that in no case in all their experience have they suffered any difficulty in that respect. The reason, I think, can be explained scientifically by the consideration of the relation of temperature to draft. If we draw a curve in which the distance from the base line represents the draft or the force of draft in inches of water, and the distance horizontally represents temperature, it will be noticed that the curve rises rapidly and then becomes nearly horizontal, that is, the draft increases very rapidly with the first increase in temperature, but after we get to a temperature of about 200 degrees the draft then increases very slightly with additional temperature. It reaches its maximum—we are not in exact agreement as to where it does reach its maximum—probably at 500 to 600 degrees. The result is that we can reduce the temperature when above 250 degrees a good deal without changing the draft but little, and that also agrees with the practical experience in the use of economizers. In other words, you would carry your chimney tempera-

ture down very low, probably to 150 to 200 degrees without affecting the draft very much. Of course you would affect it some, and you would need to have the flue large enough.

Mr. B. Harold Carpenter: I would still like to ask one more question—if the Professor is familiar with the temperature of the smoke pipe in constructions of furnaces erected in the proportions that he gives in his book.

Prof. Carpenter: I am not familiar with smoke stack temperatures on those furnaces. The furnaces the proportions of which are given there are very large furnaces; that is, they have a larger amount of heating surface than is ordinarily put in for a steam boiler. The temperature, I should say, resulting from those proportions, when the furnaces are worked to capacity, would run about 300, 350 or 400 degrees. I do not think they would run to 550 or 600 degrees, as many of the hot air furnaces do at the present time. In that case, of course, the saving to be obtained from this construction would be much smaller, but when there is a hot water attachment in connection with the furnace the cost of an economizer of this character is exceedingly small and the saving, even if the temperature were 300, would probably warrant its erection.

Mr. Meyer: Mr. President, I should like to ask Professor Carpenter about the details of the radiator. I suppose it is cast iron.

Prof. Carpenter: Yes, it is just a common cast iron radiator.

Mr. Meyer: Then another question, as to the amount of the saving due to the reduction of temperature, which I think he said was about 200 degrees?

Prof. Carpenter: It is pretty hard to tell in this particular case. The saving has been about 30 per cent., and the reduction in flue temperature has not been over 150 or 200 degrees. I think the saving would be more than in steam boiler practice, because steam is rather more efficient in picking up heat than hot air; yet I have not the data in that respect.

Mr. B. Harold Carpenter: Do you consider the additional cost necessary to put in as having practical and economical value? Does the saving warrant that?

Prof. Carpenter: That of course will depend entirely on circumstances. Now this particular construction could only be applied where there is a radiator and some hot water heating in connection with it. The cost in this particular instance might run to $25, including the radiator and everything connected with it. The saving would probably amount to that cost in the course of two or three winters—I am speaking now of the ordinary hot air fur-

nace. It would be less with the large hot air furnace where there is much more heating surface per square foot of grate, but the cost of such an arrangement is so small that I think it would usually pay a big interest on investment. The economizer practice is a very old one in connection with power plants, but I had not known of its being used in connection with heating plants. I believe it might in many cases have just as much value as it proved to have in the case cited.

The President: Is there any further discussion upon this topic? Mr. B. H. Carpenter has had considerable experience in house heating. If there is nothing further to be said on this topic we will pass to the next.

Mr. B. Harold Carpenter: I understand there is a gentleman here—Mr. Smith—and I would like to hear from him in this connection.

The President: We will be pleased to hear from Mr. Smith.

Mr. Smith: I am Mr. Smith, but I am not a member here, but through the courtesy of Mr. Connolly I was asked to come here. I am not prepared to make any extended remarks except to give my experience in the last year in the hot water system of heating of the Nemo Heater Company of Boston, wherein they make use of the kitchen fire, not only to do the cooking, but the heating entirely of a small house or of a flat—especially flats. It is done through two special ideas; the first is the fire is made to burn downwards, and the gas is then made to burn through a water pipe grate through which the water is delivered and forced around on a flat surface, on a level surface, through the radiators. I have found that it has done the work in my particular experience in a flat, about 25 by 65 feet; the one fire has done the entire work. There are several little drawbacks to it, but they, I think, are due to my own inexperience in putting it in. I could not find anybody to take it up and I was forced to take a plumber's assistant to help me put it in by myself. I think that that system has thoroughly demonstrated the fact that one fire will do the entire work, and, as Professor Carpenter has remarked, it will only be a matter of years before the cost is saved in the use of the system. Of course it would not do for speculation houses. Therefore the builders have not taken to it, because it requires a permanent tenant of six or seven years, perhaps, to get back the cost that is put into it.

The President: Does that form apply only to direct radiation, or semi-direct or indirect?

Mr. Smith: It is direct. The only thing is that the draft is

cut off from going upwards, as usual in ranges, and by its upper inlet forced to pass downwards underneath the oven, and that is one drawback I have found. It has given me so much heat that we cannot roast or bake anything except with the oven door very wide open or partly open. A mortise is cut in the partition plate so that the draft is entirely downward. That forces the coal to burn comparatively slowly, and it consumes all the vapors and all the gases that come from the coal, so that the flame is burning downwardly through this pipe grate in a blue flame.

The President: In warming a flue I presume you get your circulation by a tank at the ceiling line.

Mr. Smith: Yes sir. The tank is within a foot or fifteen inches of the ceiling. It is open air pressure, and it delivers back on a level, which I believe no other system does. The pipes, I might say, of this water pipe grate, 18 or 19 quarter or half-inch pipes are on an angle, so that the water as it comes into the grate, and the heat passing through it, forces the water up, I believe through these little pipe hills. That, I believe the patentee claims, gives an extra force and enables the water to be delivered through the radiators and down on the level back.

The President: In your actual practice it does that?

Mr. Smith: It does not. I was a little afraid it would not, when Mr. Blackmore came over and looked at it and told me he thought I would have considerable trouble of my own, and Mr. Clark also scared me, so that I did not know but what I would have to raise the radiators so as to get a better equilibrium of the delivery of the water, and that I had better put in some other means of heating, for I was depending on that. So I did that. I put in an open grate in my parlor, which is quite a large room. I have actually used that grate three times during the last winter.

The President: We are obliged for the information.

Mr. Fowler: Some time in December I visited a little apparatus in our city that was composed of a cooking range that had a water circulator in the back and the two sides of the fire pot, and the circulation of the water was first through that and then passed upwards to a small boiler made of light sheet iron with a large number of very small tubes passing through it, placed immediately above this cooking range, and the products of combustion, after leaving the cooking range, passed through the tubes of this smaller boiler and the circulation of the water was completed, after leaving the water back, through this small boiler. I should judge the boiler was 18 to 20 inches in diameter and 3 feet long, and at that time they were

doing the ordinary cooking of the house of perhaps six rooms, and apparently there was no more fire being used in the range than under ordinary circumstances, and yet they were supplying something like 300 feet of radiation. While I had no means of determining the temperature in the radiation, yet it was so hot that I could not bear my hand on it at any point through the house. There may not have been quite 300, but from 250 to 300 feet, and they claimed that they were not using in that apparatus any more fuel than is being used in an ordinary cooking range but of course I could see readily that they would be required to keep the draft of that range on all the time and at no time would there be a slow combustion going on like there is under ordinary circumstances in a residence, and whether there would be saving of any material amount of fuel I am not prepared to say, but I am going to look into the matter a little farther and devote a little time to ascertaining more definite results from this device.

Mr. Smith: I can give you a great many data of that kind, but I do not know just what would interest you most. I had 117 square feet of radiation, and the grate surface of itself amounts to three square feet. The temperature one morning was 3½ degrees outside. It was 56 in the parlor in the front, where I have but 60 feet of radiation in 3,200 cubic feet. The grate of the fire box is the same at all times. It is the same size as is ordinarily used. It is a 16 by 10½ grate. The coal used is less than a ton per month, and it is a continuous fire night and day.

The President: Have you operated this apparatus in the summer to know what the coal consumed was?

Mr. Smith: I have no data to give you as to what coal is used in the summer, because that is used very little, and we have a gas stove which we always use in the summer time preferably, unless we want to heat the boiler for washing, or anything of that sort. But the fire is simply poked three times a day, morning, noon and night, and the fire is not touched from seven o'clock in the evening until about eight o'clock next morning for breakfast.

Mr. B. Harold Carpenter: I would like to ask in case a range is used for heating a house if they use the same sized fire box both summer and winter?

The President: Mr. Smith possibly can tell us.

Mr. Smith: In the Nemo system, the way they manage that, in the place where they close the ordinary draft they have a damper and have some other way for opening that damper and let the draft off upwards, as is ordinarily used. That is sufficient to allow the

loss of heat up the chimney as usual, and still that is by direct radiation sufficient to heat the water in the boiler for the summer use without giving the radiator heat. That system is cut off.

Mr. Mackay: I am not sufficiently conversant with this, but I have had considerable experience in investigating apparatuses that were made for heating and cooking at the same time. The first one of that sort that I have had experience with was a cast iron sectional boiler with a range in front of it. The products of combustion had to go through this cast iron sectional boiler and then waste themselves into the flue. That was a fairly economical construction on account of the amount of surface that was placed on it to absorb the heat, but it was found to be unsatisfactory and was discarded. Some eight or ten years ago such an arrangement was made in this city. The description of it was very similar to this, that is a small fire box and a water back and a boiler. They took a building in the city and fitted it up. The building was never occupied, but it was used as a means of exhibiting the operation of the plant. I looked it over in cold weather, and they were using a fire that would be out of all proportion to the cooking of the house. It was a stronger fire than would ever be necessary in a range for cooking, and they were only accomplishing the heating in a very moderate way. That apparatus went out of use. A number of them—probably 50 or 75, or maybe as many as 100—were put in, and I do not know of any of them that have remained in use any length of time. They are all out of use so far as I know to-day. Another concern in another state made a somewhat similar apparatus, and I believe they make it to-day. But I know of four of them that were put in, guaranteed to do certain work in regard to cooking and also heating the buildings, and after one winter's use they were thrown out and the manufacturers of the apparatus had to bear all the expense of taking them out and also all damage that the owners sustained in having the apparatus in the building. I think it boils down to the fact that you can only get a certain amount of heat from a given quantity of fuel, and if you have not got sufficient fire box to heat and cook with you cannot heat and cook. Then, it seems to me to be a bad combination, because the range is very frquently wanted for cooking when you do not want it for heating, and vice versa. The range in an average house is not always run at a uniform temperature. Appliances on that line which have come under my notice, after they have been used for a few years have been discarded. What has been described by Mr. Smith may be an exception and I do not want to criticise it adversely.

Mr. Carpenter: Do you use the same grate summer and winter; that is the same size?

Mr. Smith: The same size grate. I said 16 by 10½. That is the size of the grate as they furnish it. But when they put that in they first remove the water back and the brick lining, and after it is installed, plaster cement is used for lining the fire box, so that the real fire box would be only 14 by 8 inches, after taking off the thickness of the plaster.

Mr. B. Harold Carpenter: Do you change it around during summer and winter?

Mr. Smith: No, sir. We put the grate that comes into the fire box after all the lining and water back have been removed. That is 16 by 10½. That is the size of the grate. But by the lining being put in on top of it it reduces the size of it. But that is permanent.

Mr. Jellett: I do not know that I can add anything in the way of information as to what is the best thing to do, but I can tell of an experiment in this direction that was conducted on a pretty large scale some years ago, and the buildings are still being heated in the same way. I believe a number of houses were erected by a man who had progressive ideas and thought that workmen ought to have more comfortable homes. He owned a piece of ground in the suburbs of Philadelphia, and he divided it into two streets. The houses are two-story houses; parlor and kitchen on the first floor and bedrooms and bath on the second. They face on a small park. The space in front of the houses is adorned with fountains and gardens and cement walks. In the rear of the house there is a narrow street about 14 feet in width in which all business is transacted. There is no access by means of wagons to the front of the houses at all. He heated these houses by an open fireplace heater. Behind the fireplace was a cast iron boiler. So far as appearances were concerned it was the usual cast iron fireplace, but instead of being plain backs and jambs there was a water back, with a deflecting plate, before the gases entered the chimney. From the open fireplace water back pipes were run in a concealed flue to the second floor, and connected to direct radiators in two bedrooms and the bathroom. There are no pipes of any kind in the cellars. There was simply this one fireplace in the parlor and three radiators above. The grate could be furnished, I presume, for about $13 or $14. The whole thing possibly would cost about $50 to $54. It was a nice looking system. I have never seen it carried out further than that. Mr. Patton who controlled the grate (whether he designed it or not I do not know), was in the wall paper busi-

ness. He was not a mechanic at all, and he told me that the first one ever used he used in his own parlor in order to heat asitting room; so I rather imagine that he was the designer of the thing and had it made to meet his own difficulties, and that the gentleman who built the small houses happened to see this particular grate and had a number of them made. There are 64 houses, I think, in the two blocks. They are in use to-day, and it was certainly twelve years ago when the work was done.

Mr. Mackay: I know the grate that Mr. Jellett describes and have used it. But there is a good deal more surface in that grate than there is in any of these range heaters that have been made to heat and cook; a good deal more surface in proportion to what they do. It is more after the description of a regular boiler when you consider that it is only expected to do one thing—give you heat and circulate the water. The amount of surface that is in it in proportion to the work it has to do is fairly in comparison with the average construction of hot water heaters.

The President: Gentlemen, you have only treated just half of this topic. You have only been talking about warming. No one has said anything about ventilation.

Mr. Paul: I do not want to occupy too much time; but I can give you in a very short way an experiment that I tried once with this question of small apparatus for house work. I had a house in which I put an apparatus of four square feet of fire surface and had a 12-inch grate, and with that I took care of 350 feet of steam surface, and I carried it to success. It was an experimental plant to find out the troubles that might occur, and before I got through I put on over 400 feet of surface. With that plant I was able to heat the house. A Perfection hot water stove was used as a boiler; and I was able to carry fire all night, and the house was in fair condition in the morning.

The President: Mr. Davidson, what is your experience in this direction?

Mr. Davidson: I have had one similar case to that. It was in the Worcester Telephone Building. In that case we had a condition to be met where the air was brought from the roof of the building in tiles down through the wall, and then in the arches under the floor it was divided so that one-half was used for the air coming to the radiator which was a circular form and passed up into the room, and then the other half was used for the exhaust system which connected to the fan and the fan chamber on the roof. We had about six of those radiators and six large exhaust ducts which connected

with the fan. We had no trouble with drafts there and the building is perfectly heated and ventilated.

Mr. Mark Dean: A friend of mine in ventilating a house in what I thought a very nice and cheap way, put in a hot water plant, using direct radiators in the first floor, and a very large indirect radiator in the hall. To get ventilation he put false fireplaces in the rooms on first floor and ran a galvanized iron pipe to the attic. In the baseboard of the bedrooms above, in which there was no radiation, he placed a galvanized iron foul air duct leading from the baseboard to the attic. All these galvanized iron ducts together with those from below came into one common flue in the attic with some direct radiation inside to help the ventilation. He placed transoms over each of the bedroom doors that admitted the warm air into them above the head line. The foul air ducts running through the baseboards carried off the vitiated air. The bedrooms were kept very comfortable from the indirect radiator in the lower hall. This reduced the number of radiators and gave fresh air throughout the house.

The President: Is there anything further to be said on this topic?

Mr. B. Harold Carpenter: I still think the furnace is the best.

TOPIC NO. 10.

**Simple methods of breaking up drafts in forced ventilation work.**

The President: The topic is rather broad. Of course it might be viewed in regard to the safe velocity, or as to the form of the entrance; that is the inlet and the outlet.

Mr. Dean: I think as to the form of entrance the most simple way is to make a large entrance of sufficient capacity to allow the air to enter at a slow velocity. In a church that I know of the ceiling in the lecture room below is low; the air is brought in (Blower system) about 12 or 15 inches, perhaps two feet below the ceiling; the drafts were quite perceptible in the room, so they put in some deflectors. Those deflectors influenced the currents of air, but did not stop the trouble, although they changed the location of the troublesome drafts.

The President: That could easily be remedied when you are using warm air, and the drafts of course occur when you turn on cold air. When you are getting simply the ventilation without the heat, why that is another thing.

Mr. Dean: The plant that I am speaking of has two steam coils; the air is forced over them by an electric motor. The ceiling is low, and the room is 44x45 feet. The point that I make is this,

that while they deflect the currents of air the air will either strike the side walls and be thrown inward, or strike the ceiling and be thrown down—there are two of those inlets, one on either side of the end of the room. I have noticed, when standing in the room about 15 feet out from the wall between the two inlets, that I would feel the air on my head. It seemed to me that the currents of air were thrown up against the ceiling and rebounded almost to the floor. The slats in the deflectors being set at a comparatively sharp angle and the ceiling being low it naturally forces the air currents downward.

The President: Probably the velocity is too high.

Mr. Dean: There is no question about that; the velocity is too high.

The President: Mr. McMannis, can you give us any information on this topic?

Mr. McMannis: I have been working on that scheme for a number of years and yet I have only partially succeeded. I have used what we term diffusers; have plates fitted in at the inlets at different angles, so that it diffuses the air throughout the room. Where I get the air say at a velocity of about five feet a second, under those conditions I can get the air into the room with very little if any perceptible draft, unless the engineer is careless and allows the temperature of the air to fall. But so long as the air enters at 68 or 70 there is very little fault found. The greatest difficulty is with the vent openings on or near the floor. It is seldom we can get an opening there of more than three and a half or four feet. In our new buildings we are getting five feet. In those cases we can get the air out of the room without feeling any draft. But where they are below that size there is more or less fault found, especially where the seats are in close proximity to the vent openings. Where I have the space I have put up screens so as to diffuse the air as much as possible. At the present time we are so constructing our wardrobes in the classrooms in some cases as to allow the wardrobe to butt up against the side of the vent flue. In those cases we take the lower panels of the wardrobe out, and put wire screens in, and that has a tendency to diffuse the air throughout the whole length of the wardrobe and breaks that draft so that it is scarcely perceptible. But where we have to concentrate at one point the conditions will not allow us to subdue those drafts. The only means that I can see to overcome them is to have sufficient outlet, large vent flues and large heat flues.

The President: And slow velocity necessarily?

Mr. McMannis: Yes. That is the only means.

# LX.

## SEMI-ANNUAL MEETING

OF

## THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS.

Held at the United States Hotel, Saratoga Springs, N. Y., July 21 and 22, 1899.

The meeting was called to order on July 21 at 2:35 P. M. by First Vice-President D. M. Quay.

The Chairman: Gentlemen, and members of the American Society of Heating and Ventilating Engineers—In the absence of your worthy president it becomes my duty as first vice-president, to call to order this, the third semi-annual meeting of the society. The secretary has a letter from Mr. Adams stating that he cannot be here on account of pressing business. It is quite unfortunate and I am very sorry indeed that Mr. Adams cannot be present at the meeting. The first business, according to our rule, will be the roll call. The secretary will please call the roll.

Secretary Mackay: Before calling the roll I would announce that at the meeting of the council held on June 16, the following persons were elected to membership in our society and have qualified:

Henry L. Hall, New York, member; John Jeffreys, London, Eng., member; Joseph Nelson Russell, London, Eng., member; R. Barnard Talcott, Supervising Architect's Office, Treasury Department, Washington, D. C., member; William A. Dunn, Newark, N. J., member; Albert Theodore Kellogg, Kewanee, Ill., member; William Edwin Williams, New York, member; John Richard Shanklin,

Charleston, W. Va., member; James Harry Davis, Chicago, Ill., member; Andrew J. Paul, Boston, Mass., member; Frank Leavenworth Connard, Reading, Pa., associate; Warren Webster, Camden, N. J., associate.

The secretary called the roll. The following gentlemen were present:

G. E. Adams,
James H. Blessing,
R. C. Carpenter,
Frank K. Chew,
Albert A. Cryer,
Judson A. Goodrich,
J. H. Kinealy,
James Mackay,
W. M. Mackay,
William McMannis,
Andrew G. Paul,
D. M. Quay,
H. A. Smith.
Theodore S. Webster,
Warren Webster,
Wiltsie F. Wolfe.

The Chairman: Our constitution states in the second section of Article 2 that fifteen members present at either an annual or semi-annual meeting shall constitute a quorum to do business. We will now proceed with the regular order of business.

Mr. Wolfe: I would move, to save time, that the regular order of business which is customary at the regular meetings be dispensed with at this semi-annual meeting, and that we proceed to the reading of papers. (Seconded and carried.)

The Chairman: The programme that has been prepared by the board of managers is before you. The first in order is the president's address. He not being present, and I having no address to make in his place, we will have to dispense with that part. The next is a paper on "The Calculation of Centrifugal Fans for Ventilating Purposes," by Mr. H. Eisert, member of the society.

In the absence of the author the paper was read by Prof. R. C. Carpenter. The paper was discussed by Prof. Carpenter and Prof. J. H. Kinealy.

The Chairman: If there is no other discussion we will diverge a little from the programme at this point. Mr. Jellett was appointed at the last meeting to confer with the American Institute of Architects with reference to the question of the relation of the engineer and the architect and to report at this meeting. He has sent a written report, and I will ask our secretary to read it.

Secretary Mackay: I would state that Mr. Jellett fully intended to be at the meeting, but found that the press of business, and the absence of his partner in Europe, made it impossible to be here.

The secretary then read the following report:

REPORT OF MR. S. A. JELLETT, MEMBER OF THE SOCIETY, ON "THE RELATION BETWEEN THE ARCHITECT AND THE HEATING ENGINEER."

Philadelphia, July 20, 1899.

American Society of Heating and Ventilating Engineers,
Wm. M. Mackay, Secretary,
United States Hotel,
Saratoga Springs, New York.

Dear Sir:—

At our last annual meeting, a paper was read, prepared by Mr. T. N. Thomson, on the "Relation Between the Architect and Heating Engineer," which brought out considerable discussion on the general subject. The result of the discussion (as our members will recollect), was that the writer was asked to become a committee of one to consider the whole question, to take it up with the Secretary of the American Institute of Architects, and report to the next meeting, which I take to be the semi-annual meeting; the intention being, as I understand it, to have the whole matter discussed at the semi-annual meeting, with the idea of having a paper prepared and sent to the architects and architectural and engineering journals, to open up the general question of the relationship between the architect and engineer, compensation for services, and the rights and authorities of each party in connection with any work where the architect and engineer are joined.

I have been exceedingly busy since the annual meeting in January, and have not been able to give the matter the attention it should have. I have written to the Secretary of the American Institute of Architects, Mr. Glen Brown, whose office is at the Octagon House, Washington, D. C.; this being now the official headquarters of the American Institute of Architects. He promised to bring the whole matter before the Executive Committee at their meeting on July 17, and he hoped to be able to give me an answer on or before July 20; but, up to the present writing (July 20, P. M.), I have not heard from him. Should his reply be received in time, I will forward it to the meeting.

It seems to me that the matter should be discussed at this semi-annual meeting, and would suggest that it be discussed on the following lines, and that the notes of the discussion be handed over to the committee who will be selected to take charge of the matter, as a basis on which to prepare the paper for distribution to the architects and engineering journals.

Mr. Thomson, in his paper, dwelt exclusively on the result, from an engineering standpoint, that is found in buildings where no engineer had been employed, citing particularly the bad arrangement, the interference with the proper use of the building, and the general unsightliness of the construction. It is not necessary for me to go into the details of this, as nearly all of our members are familiar with it from the advance copies that were furnished. The matter was discussed by Mr. Reginald P. Bolton, Mr. Wm. Kent and others at the meeting, taking up not only the ground covered by Mr. Thomson, but also the question of fees for the engineer, the injury done the consulting engineers by the architects, by preparing plans and specifications for work free of expense to them, and also the question as to whether the architect or owner should pay for this additional engineering service. Extracts from the proceedings of the January meeting will cover this ground fully.

After giving the matter considerable thought, it seems to me that the question resolves itself into a very few divisions. First, as to the necessity for employing heating and ventilating engineers on modern buildings, and this, I think, we all agree is an absolute necessity if proper results are to be obtained, and I think that a great majority of architects agree that this is the best thing to do, but the "bone of contention" seems to be—who shall pay for it, and how much shall be paid for it.

As a basis for discussion, I would suggest the following arrangement:—That the compensation for heating and ventilating engineers, for preparing the plans and specifications for work, shall be, on work costing $5,000 or less, five per cent for plans and specifications and two and a half per cent additional for superintendence of the work; on work costing between $5,000 and $10,000, four per cent for plans and specifications and two per cent for superintendence; on work costing over $10,000, three and a half per cent for plans and specifications and one and a half per cent for superintendence. In all cases, travelling expenses at cost to be added, where the work is at some distance from the town in which the consulting engineer has his office.

I would suggest further, that where the architect is compelled to pay for the engineer's services, out of his fees, that is, where he does not get an additional allowance beyond his regular commission from the owner, that a rebate be made to him of 25 per cent on these commissions, for preparing plans, and for superintendence. That the heating and ventilating engineer is to furnish four complete sets of prints from his drawings and four typewritten sets of

complete specifications, and that where additional prints are required, beyond the four sets of specifications, that they are to be charged for at cost. That if the heating and ventilating engineer is asked to make a preliminary report and approximate cost of the proposed operation, on work costing $5,000 or less, he should get two per cent for making this preliminary report and approximation of cost, and one and one-half per cent on such work where the cost is between $5,000 and $10,000, and one per cent on work where the cost is over $10,000.

If, after discussion, a basis of rates is agreed on as being fair, they should be printed as the schedule of rates of this Society and copies sent to each member. Before sending these out, it might be well to have a consultation with the Institute of Architects, as to the best method of procedure in the matter, as many of the architects feel that this engineering work is exclusively and entirely for the owner's benefit; that the object of employing an engineer is to give the owner either a very much better mechanical equipment at the same cost, or a much more economical operating plant than he would otherwise get, and that as the engineer is employed for the sole reason to save the owner either in original construction or in operating expense, that he should be the one that should pay the cost of the engineering services. I think this is a perfectly fair ground to take, and if handled in the proper way, the majority of owners will agree with us. We should have, in my judgment, a consultation with the architects on this basis, and if possible arrange for concerted action in the matter.

We should also arrange with the Master Steam and Hot Water Fitters' Association, if it can be done, that the members of the Master Steam Fitters' Association will not prepare plans and specifications for architects and owners, for the mere sake of getting the work; that is, without compensation. This need not necessarily mean that they should not make the owner an approximate estimate outlining to him what they would advise doing, but would prohibit them from making scale drawings giving all information and data necessary, and furnishing complete specifications such as the engineer is expected to furnish. The result of this practice of securing plans and specifications for nothing is that the steam-fitter does more engineering in connection with plans and specifications with the idea of getting the work, than he does studying the interests of the owners, in connection with the economy of operation of the plants. He will frequently arrange that the sizes shown on the plans and called for in specifications shall be larger than he intends

to figure on, and he will go further in many cases, having parties whose goods he specified protect him by a reasonable commission. It is perfectly right that he should be paid for his services, and as it has grown to be a customary thing for an architect to accept work of this kind, it necessarily follows that it cannot be broken up in a day, and that there will be quite considerable opposition to the movement; but I think if the opinions of the leading steam-fitters in the country were obtained in the matter, that they would be in favor of cutting off this item of expense in their business, from which there is a doubtful return.

Again, the question as to the position in which the architect places himself, with relation to the contractor from whom he gets plans and specifications free, should be discussed; but, it should be discussed in an entirely impartial manner, as some of our members felt inclined to blame the architect for getting work done for nothing. Whereas, as a matter of fact, the blame should be placed to a great extent, on the other party, namely, the steam heating contractor, who will come to the architect and offer to do this work for him for nothing. The architect cannot wholly be blamed for accepting service of this kind, when it is so freely offered him; but, on the other hand, the architect that accepts such service free, is under obligations to the party furnishing him the plans and specifications. He is under obligations to help him get the work, or to repay him in some way, and it may not be to his client's interest that the party preparing the plans should have the work.

This is rather a delicate question to discuss, but the problem must be faced, and I think the leading architects in the country are of the opinion that the engineer is a necessity on a modern building, and that the engineer is entitled to compensation for his services, and the problem with them is, who shall pay for it. They do not feel that out of their present commission, which was fixed a great many years back before the period of modern engineering, that they should be called on to pay for it.

I think further, that it is right that the heating and ventilating engineer should work in conjunction with the architect, and under his direction. The architect being the designer and creator of the building, and being held responsible for the final results, should have all engineers subordinate to him in the designing of the building; that he should consult with the engineer as to the general arrangement and prepare the plans for his building so as to give them reasonable opportunities to put in the proper plant for the building They in turn, as good engineers, should assist him in every way

possible to produce the best results not only economically, but to arrange the mechanical plant so as not to interfere with the general design and use of the building, and they should also keep in mind the proportion of cost of their work to the total cost of the building. In other words, the commercial problem should be as carefully considered by them in their section of the work, as it must be by the architect in the total cost of the completed structure.

I trust that the discussion will be full and free, and that the result of the discussion will be of material benefit to the position of the heating and ventilating engineer.

I would suggest that it would be better to have a committee of three than of one, to take up this matter, after this semi-annual meeting, and get it into proper shape; and, as I am particularly pressed for time, and will be for some time to come, I would particularly request that I be not appointed on the committee, although, I would be glad to furnish the committee with any information that I have, or can obtain. With best wishes for a successful meeting,

Yours very truly, S. A. JELLETT, Committee.

The Chairman: You have heard the report of Mr. Jellett. What shall be done with it?

Mr. Wiltsie F. Wolfe: Mr. Chairman, I think this is too important a matter for us to take any action upon at present. If we weigh it carefully, it seems to me it is either the ladder we rise by or the block that we will fall over. If one and all adopt that as our rule, we shall then have opened the door for the best engineers of the country to come with us, the same as the American Society of Architects. It is a matter worthy of very careful consideration and a matter that could be debated in a meeting more largely attended than this, in my judgment.

Mr. William McMannis: Mr. Chairman, I would move that this discussion be laid over until the next meeting when Mr. Jellett can be present. I am sure that he would like to take part in thaf discussion. (Seconded.)

Prof. Kinealy: I would like to amend by adding the words—"and that the report be printed for distribution before the next meeting." (Seconded.)

The Chairman: The motion, as I understand it, is that the discussion of this question be postponed at this time and that the report be printed and distributed to each member before the next annual meeting and that the committee be continued. Are there any remarks on the motion?

Secretary Mackay: It seems to me that if we do as the motion or the amendment calls for that we are going to lose valuable time. It is an important question, and this is something that has been asked for year after year since we came into existence five or six years ago. I think that it would be wise to act on the committee's suggestion, that a committee of three be appointed to carry out those lines which have been suggested and to consult with the Institute of Architects. If we let this matter go over until our next annual meeting then a committee will be appointed and a year from then we will be doing something. It seems to me we can accomplish a great deal of good and do no harm by moving in this matter at this time, and if it is in order I would move an amendment to the amendment, that a committee of three be appointed, as suggested by the committee's report, to carry out the sense of the report and report the results at the annual meeting.

Prof. Carpenter: I would second that amendment, for the reason that it seems to me a very good policy to carry out. It does not necessarily lay out any particular line of action, but gives us something definite to consider at our next meeting.

Mr. Wolfe: I oppose the amendment for this reason, that the committee as it stands at present is a committee of one—Mr. Jellett. He is in communication with the National Society of Architects. Their semi-annual meeting has been held within a few days. Their secretary has been and probably will continue to be in correspondence with Mr. Jellett. It is too serious a matter for us to act for the society as a whole, and unless we do act as a whole we had better not act at all. If we are going to act on this thing we want to act as a body, as one man, and stick to it, and on that basis we will get the best engineers in the country with us. With a committee of three in such matters as this, as you all know, each member of the committee is very apt to leave it to the others. We cannot meet with the Society of Architects until their next annual meeting, which comes before ours, and we cannot meet them then anyhow, because we have no action to take, and as it stands now, the sense of their meeting would be transmitted to Mr. Jellett, and of course no further action will be necessary until the annual meeting, when it will be discussed by the society, when there will be, of course, a larger attendance than there is here now. I believe the amendment unnecessary, for that reason; and it will not involve putting any more work on Mr. Jellett because the work is being done.

The Chairman: I think probably that a point of order might be raised that the only thing we can do now is to continue the present

committee. We have not a quorum present, and we have passed a motion to the effect that we are not going to take up the regular order of business at this meeting, so we cannot appoint a committee of three and give them power to act so that they could do anything. I believe, therefore, that the only thing we can do is to accept this report, and to continue Mr. Jellett as a committee to continue his work and make a final report at the annual meeting.

Secretary Mackay: I question if we can do even that. As we have no quorum all these motions are out of order. It would seem that the report would only lie on the table until there is a full meeting of the society.

The Chairman: Suppose we simply let it lie on the table. The motion is out of order so we will not pass it at present.

(Further action was taken on this subject at the evening session.)

The Chairman: The next in order will be "Description of Arrangement for the Heating and Ventilating Exhibit at the Paris Exposition of 1900," by Mr. W. F. Wolfe. We are to be congratulated that one of our members has been oppointed to represent the United States at the Paris Exhibition and we should be pleased to hear from Mr. Wolfe.

Mr. Wolfe read a description of the arrangement for the heating and ventilating exhibit at Paris Exhibition of 1900.

## REPORT OF W. F. WOLFE, MEMBER OF THE SOCIETY, AND EXPERT IN CHARGE OF THE AMERICAN EXHIBIT OF HEATING AND VENTILATING APPARATUS AND ALLIED INDUSTRIES AT THE PARIS EXPOSITION, 1900.

Mr. President and Gentlemen of the Society:—

Having been associated with you since the Society was organized, I am naturally familiar with its aims and purposes. At the time of our organization the business of heating and ventilation was looked upon rather as a trade than as a profession, more particularly, perhaps, in the matter of heating than of ventilating, but the so-called ventilation of those days was a very indefinite quantity. It could probably be covered by the general specification that a sufficient amount of air should be transmitted through an apartment to produce good ventilation. Since then we have been working for the advancement of the business up to a professional standpoint, in the hope of rising above those who could simply warm and distribute a volume of air, regardless of any fixed standard as to quantity, method of distribution, purity and general efficiency. I esteem it an honor to be permitted to appear before this Society and to

announce that the science of warming and ventilation has reached such a point of official recognition that an especial department has been devoted to this branch in the Paris Exposition of 1900. To be sure, the space allotted is very small, being in its entirety 2,253 square feet, sub-divided by several passageways, leaving a clear floor space of only 1,385 square feet. Added thereto, there is approximately 1,000 square feet of wall surface which can be utilized. When you consider this small total area and the expensive classification of the exhibits given in the subjoined list, under the head of Heating and Ventilation, Group 74, United States Exhibit, you will realize how difficult it will be to make a representative and typical showing as to the real advancement made in this line.

APPARATUS AND PROCESSES FOR HEATING AND VENTILATION.

1. Systems of heating and ventilation.

Heating by steam, hot water, hot air, and their combinations.

Methods of conveying and distributing steam, hot water and hot air used separately or in combination.

Natural ventilation; ventilation by exhaustion; ventilation by mechanical means, and their combinations.

Plans and models of buildings heated and ventilated; public buildings, factories, dwelling houses.

2. Apparatus.

Stoves and furnaces peculiar to the various systems of heating.

Radiators of heat of all kinds and sizes. Steam or hot water boilers. Steam or hot water ranges. Hot air pipes. Hot air stoves.

Ventilators and displacers of air. Up-draught ventilators. Methods for the direct renewal of air to warmed and ventilated apartments.

3. Apparatus for household heating. Preparation and cooking of food.

Stoves or chimneys, fixed or movable.

Apparatus for heating by petroleum or by gas.

Steam cooking ranges. Kitchen ranges of all kinds. Stoves used at the same time for cooking food and for warming apartments. Stoves adapted to certain special forms of cooking. Stoves and apparatus, fixed or movable, used for preparing food or beverages in large quantities.

Ventilators operated by the wind or by differences of temperature.

Sanitation and ventilation of kitchens and of small living rooms.

4. Accessories to heating and ventilation.

Measuring and registering apparatus: thermometers; self-registering thermometers; pyrometers; anemometers; monometers for

measuring low gas pressures and for indicating the level of water in pipes; appliances for measuring the flow of steam through pipes; registering apparatus of every kind.

Thermostats: distributing and regulating apparatus; regulators of temperature; regulators of draft; regulators of pressure; automatic drip cocks and air cocks; cocks specially fitted for heating apparatus.

5. Chimney fittings.

Dampers for chimneys. Closing of flues. Openings for hot air and ventilation. Gratings and plates. Metallic casings for heating apparatus. Special sheet iron. Chimney pots and smoke consumers.

6. Fireplace and chimney pottery.

Stoves and chimneys in earthenware. Ornaments. Earthenware of every sort for the fireplace. Refractory materials for hearths, hot air stoves, stoves and chimneys.

7. Accessories.

Hearth furniture: fire lighters. Ash sifters. Utensils for cleaning and repairing.

However, small as the space is, the allottment of it shows progress in the art, and I congratulate you as a society, and each member individually, fully believing that you and they have helped to do their part in bringing this profession to the world's notice.

This being really the first opportunity ever afforded American manufacturers and engineers to exhibit to the world the progress that has been made in the science, the art and the manufacture, within the United States, in the several branches of warming and ventilation, the exhibits at Paris in 1900 should be characteristic and typical to the highest degree.

An individual exhibit, by all or several manufacturers, that would be representative of the advances made by the people of the United States in this branch of manufacture and profession, is impossible, as the entire space allotted is small and the expenses thereof would be enormous.

It is only by the united efforts of all engaged in producing such articles as are typical of their kind (see description, Warming and Ventilation, Class 74) that the world can be shown how advanced we are, how we have progressed in the art to date and why the markets of the world should be opened to us. Individually, we would be weak; united in this exhibit we would be the strongest, the best and in every way representative leaders in this branch, and at small expense when subdivided between the collective exhibitors.

The appropriation made by Congress (approximately $1,000,000),

to be expended by the Commissioner of the United States to the Paris Exposition in 1900, has, of necessity, been largely expended in exploiting the plan and method to the people, contracting for buildings and other equipment, canvassing, and the necessary great outlay for printing, rents, clerical forces and various but essential sundry expenses attendant to the preliminary work, leaving the available balance too limited to make possible a display that would be representative of the great resources or convey a proper impression to the world as to the supremacy of the United States in all branches of science, trade and manufacture within this classification.

The following is a general outline as to how the exhibit in this Department (No. 74) will be made and the result it hopes to attain thereby.

Each exhibitor will be requested to deliver his goods in New York City, suitably packed for export, at a place and time hereafter to be directed.

The articles will then be entirely cared for by the Commission upon the following lines: They will be insured against loss both fire and marine, shipped to France accompanied by an agent of this Department, unloaded there, transferred to railroad vans and shipped to the Exposition grounds in Paris, unloaded, and the cases being removed will be properly packed, numbered and stored in warehouse prepared for that purpose until the close of the Exposition.

The exhibit will then be set in its allotted space, all care being used to bring it into prominence, proper decorations, backgrounds and draperies being used to make it effective and artistically attractive.

There will be provided a sufficient number of interpreters in attendance at all times, to explain exhibits to visitors speaking the Japanese, Chinese, Portuguese, Spanish, Russian, German, French, and other languages found necessary.

There will be in continuous attendance also proficient Americans, conversant with the details of all exhibits, to see that the same are properly cared for, operated and brought to the attention of the visiting world in a commercial manner.

Joining with other Departments, a corps of local agents will be employed, whose duty will be to personally interview, as far as possible, each visitor to the Exposition and direct him to the exhibit in which he may have special business interests. Such visitors will be supplied with cards, and will receive all possible courtesy and

information upon presentation of the same at the exhibit. His name will be taken, and each exhibitor will be advised from time to time, by circular letter, of the full name and business address of every caller interested in his particular line, with the suggestion that he place himself in communication with the visiting party at his home address.

Due diligence will be used in endeavoring to sell from samples exhibited as many goods as possible at prices quoted thereon by the exhibitor.

When possible the exhibits will be shown in active operation, electrical power, water and gas being supplied without charge.

Circulars or such other advertising matter as may be furnished by the exhibitor will be properly distributed to visitors in interest.

At the close of the Exposition each exhibit will be repacked carefully and returned to New York, subject to the exhibitor's order, or shipped to any other point that may be designated by him.

Owing to the limited space allotted, it is now estimated that the cost for space to each exhibitor, including attendant services and necessary expenditures for the carrying out of this plan in a thoroughly first-class and creditable manner, will be $20 per superficial square foot of floor, side wall or show-case space. This will cover the entire expense to the exhibitor from the time of the arrival of the exhibit in New York until its return thereto, excepting he orders it shipped elsewhere. Minimum charge for any article exhibited being $100, and for book, pamphlet, or drawing, $25. It is not possible to conceive how any individual exhibitor can attain corresponding results by his personal efforts in careful canvassing, thorough interpretation, distribution of printed matter and constant attention to all visitors, with strong endeavors to make sales, without an increase in expenditure beyond all proportion.

All exhibitors will be notified a month or as much in advance as possible of the visiting of the Juries of Award, so that each exhibitor can visit Paris at his own expense and explain his own exhibit to the juries, should he care so to do, and thus avoid waste of time.

Exhibitors also have the privilege of placing their own representative in charge of their exhibit, the expense thereof being assured and paid by such exhibitor.

This explanation, as I said before, gives you a general idea of our purpose and intention. The few photographs I have, which are subject to your inspection, will possibly convey a clearer idea of the allotted space than the figures given, and it is with the assent of Mr. Hulburt, Director of the Department of Varied Industries to

the Paris Exposition of 1900, under which general grouping Heating and Ventilation are placed, that I address your Society with a view of requesting a discussion, hoping that suggestions may come from you, as the representative Society of Heating and Ventilating Engineers of the world most competent to advise as to the general prominence that shall be given varied exhibits in this department, with the end in view that the world at large must stand convinced that the United States is in advance of all in this particular branch. As before stated, we shall thank you for any suggestions you may submit.

Mr. Wolfe: There is a general outline of the plan. If it can be bettered we would like to know it. You must remember we have to make an exhibit of stoves, cooking ranges and so forth, that have nothing to do with heating and ventilation, and which are entitled to a showing, of course, as much as heating and ventilating, and the question comes what percentage of space should be devoted to articles of that kind. We can eliminate high pressure boilers, because those will be shown in the machinery department. We can have only low pressure boilers here, of course. What percentage shall be allotted to them and what percentage shall be given to the other articles specified?

Mr. Andrew G. Paul: It seems to me that in this matter the society desires to do all that it possibly can to assist Mr. Wolfe, and therefore it would be well if he can give us an outline of what special assistance we can render, either by appointing a committee to help him or by making an exhibit as a society covering certain up-to-date methods. It seems to me that we have only to get from him what he wants us to do and then we would only be too happy do it.

Prof. Kinealy: Mr. Wolfe has given us an opportunity that ought not to be lost. We are being recognized now officially, and a committee ought to be appointed, and that committee ought, I think, to have three men who are in the east who can meet Mr. Wolfe and confer with him. I therefore move that a committee of three be appointed to act for the society and to aid Mr. Wolfe. (Seconded.)

Prof. Carpenter: It has suggested itself to my mind that we could perhaps do most good to the cause, to Mr. Wolfe and to ourselves, by endorsing the plan which he has presented. I believe that the matter now is in excellent hands; that a committee could not assist him in any material way. But I do believe we could assist him very much by strongly endorsing these plans which he has presented.

The Chairman: I am glad that Prof. Carpenter made the remark he did. I think the society should feel highly honored, and if there

is any way in which we could express ourselves to the parties who have appointed Mr. Wolfe, I should be glad of it. The fact of one of our members being appointed to this position is one honor, and the next one is the fact of our society being recognized and this question being referred to us as a society for suggestions by the United States Commission. If we could express ourselves in any way that would show our appreciation of the honor, and then not only endorse the appointment of Mr. Wolfe, but also endorse the plan that he has suggested here, and leave Mr. Wolfe to carry out the matter in connection with the Board of Managers, I suppose that would be a very good arrangement.

Mr. Frank K. Chew: This comes to my mind as a way of dealing with the question: "Resolved, that the plan as presented by Mr. Wolfe meets the approval of the American Society of Heating and Ventilating Engineers, and we would suggest that the varied interests should be allotted a percentage of the space provided in accordance with their importance and appoint the following committee to aid in this procedure, subject to the approval of the commission." That enables the people who know how much more space is needed by one than by another to say that such an interest should have, say, fifteen per cent. and some other interest so much per cent., and when Mr. Wolfe and his architects say we have so much floor space and so much wall space, to aid in dividing that up. None of us would hesitate to say that we can divide that space up decidedly better than officials of the Government who are not conversant with the size and shape and character of the goods.

Prof. Carpenter: I would suggest the division of this resolution into two parts; first, a resolution endorsing the general plan, entirely independent of any committee, and then make the question of committee work another consideration. I suppose it is generally understood that this committee could only offer suggestions to Mr. Wolfe. But I think we would accomplish more by having a simple resolution endorsing the general plan and then a second resolution authorizing a committee.

The Chairman: Prof. Kinealy made a motion and it was seconded that we appoint a committee of three. I will consider that motion in order unless you wish to have the other one come on first.

Prof. Kinealy: I will withdraw my motion, Mr. Chairman.

The Chairman (to Prof. Carpenter): What is your motion now?

Prof. Carpenter: That the general plan that was presented by Mr. Wolfe be endorsed by the society. I would move that as a resolution. (Seconded.)

Prof. Carpenter's resolution was carried.

The Chairman: Is there any motion to appoint a committee?

Prof. Kinealy: I move that a committee of three be appointed to aid Mr. Wolfe, and assist him in any way he wishes.

The Chairman: I would like to ask if Prof. Kinealy will explain his motion.

Prof. Kinealy: If this society endorses this motion, the committee will be a committee of the society and that committee must report to the society and what they have done will go on the minutes and there will be a record of it. In the meantime they must give Mr. Wolfe every aid that they can. They must report to us what they have done, and there will be a record, and it will be a record independent of Mr. Wolfe, as it should be.

The Chairman: I should understand that in the meantime, before our next meeting, if it was necessary for this committee to act, that they would have the power to act as representing the society, as Mr. Wolfe may suggest to them. The motion is that a committee of three be appointed to confer with and, if possible, to aid Mr. Wolfe. You have heard the motion. Are there any further remarks?

The motion was carried.

The chairman later appointed as the committee Prof. Kinealy, Prof. Carpenter and Mr. Frank K. Chew.

The Chairman: The next on the programme is report of the school house committees. As Prof. Carpenter is not sure that he can be here to-morrow morning he has asked that his paper be read now in place of this report on "Warming and Ventilation of Schools." Is there any objection to making this change? If not we will now hear Prof. Carpenter's paper on the "Investigations of a Blowing Fan."

Prof. Carpenter read the paper. It was discussed by Prof. Kinealy, and Prof. Carpenter replied.

The Chairman: The secretary has a few communications which we might have read at this time.

The secretary read letters from Messrs. John Gormly, B. H. Carpenter, Stewart A. Jellett and J. Jeffreys, regretting that they could not be present.

Secretary Mackay: I would state that the Board of Managers at their last meeting decided on the date of the annual meeting, which is to be Tuesday, Wednesday and Thursday, January 23, 24 and 25, 1900. The meeting on Tuesday will be in the afternoon and evening. On Wednesday in the afternoon only; on Thursday in the afternoon and evening.

The meeting then adjourned until eight o'clock P. M.

EVENING SESSION.

The meeting was called to order at 8:35 P. M.

Messrs. John K. Allen, Thomas F. Cushing and H. Gilbert Hart were present at this session in addition to the gentlemen whose names were previously noted.

The Chairman: The first subject on the programme will be Prof. Kinealy's paper on "Heating with Steam at or below Atmospheric Pressure."

Prof. Kinealy then read a portion of his paper and explained the diagrams by means of lantern slides.

The paper was discussed by Prof. Carpenter and Mr. Warren Webster.

The Chairman: It has been suggested that we might take some action on Mr. Jellett's report which was read this afternoon and was postponed for the time being, if any one has anything to offer on that question.

Mr. Wolfe: I would move that the report be received, and the committee continued and report again at the annual meeting. (Seconded.)

Mr. James Mackay: I would like to ask for a little information on that report. This refers to Mr. Jellett's letter. Didn't he express himself as being desirous of having the society take some action?

The Chairman: Yes; he said he wished us to discuss the question and appoint a committee.

Mr. James Mackay: Wouldn't it look better on our part to take some action to show that we were energetic, to show that we still had the subject in line and were trying to do something, just as Mr. Jellett suggests? It looks to me as though that would be the proper action—to do something rather than leave it just as it has been or leave it unfinished. If we are waiting on the architects and they are waiting on us, nothing will be done. Perhaps we can do nothing, but it might be well enough to try.

Secretary Mackay: I will state that the members of the society as a whole are united on this subject, and if you were to see the many letters that I have received, particularly from those who are following the profession of consulting engineers exclusively and not engaged in either manufacturing or contracting, you would not hesitate to move in the matter. I would like to read the last clause of Mr. Jellett's report. I think that will bring it vividly to your

memories again. He ends by saying: "I would suggest that it would be better to have a committee of three than of one to take up this matter after this semi-annual meeting and to get it into proper shape." With that in view, Mr. Chairman, I would move in amendment that we add two members to that committee as requested by Mr. Jellett.

The Chairman: It is moved and seconded as an amendment to the motion that we add two members to Mr. Jellett's committee to act with him. Is there any discussion of this amendment?

Mr. Wolfe: The only reason why I have said anything in this matter is that it seems to me it is a very important step for this society to take, as to fixing the charges of engineers; that is, our fees, and that should come before an annual meeting so that it could be voiced by a great many more people than there are here. There might be other work to be done if this committee was added to. They might get an expression from each member, if he was willing to assent to such a motion or something of that kind. Aside from that I do not see what can be done until we hear from the architects.

Secretary Mackay: I would like to read what our society did in session last January in connection with this matter:

"The President: It has been moved and seconded that the paper and discussion relative to the paper be published for use at our semi-annual meeting and that Mr. Jellett be appointed a special committee of one to bring the matter before the American Society of Architects and such other parties as in his judgment may seem best."

Ever since our society was organized that was one of the principal objects it had in view—to establish a minimum price for all engineering services. Clause 8 of Section 4 of the first article of the constitution stated as one of the objects of the society the establishing of a uniform scale of prices for all professional services.

The amendment and the motion were then both carried.

Vice-president Quay at the next session appointed Prof. R. C. Carpenter and President Adams as the two additional members of the committee.

Secretary Mackay: There are some topics for discussion. The first is: "Should not our society condemn the practice of certain specialty men who in order to sell their system or specialties are making plans of heating systems? Is it not true that these plans are often badly designed and usually presented by irresponsible persons? Does not such practice lead to poor results, and is it not detrimental to the best interests of the members?"

Mr. Wolfe: I think our charter covers that ground. We are

organized under our constitution to promote the advancement of the art and necessarily to condemn the bad practice referred to.

The Chairman: Is there any further discussion of the topic?

Prof. Carpenter: I think Mr. Wolfe has not understood that topic. I think the topic of discussion is somewhat similar to the resolution. It refers to the practice of getting engineering work, such as the making of plans and specifications by machinery contractors and others, without charge. It is right in line with Mr. Jellett's resolution.

Mr. Wolfe: I think we are all agreeable to such a motion, but we cannot stop the practice.

The Chairman: I think Mr. Jellett's paper pretty well covers that question. Is there any other discussion? If not we will take up the next.

Secretary Mackay: Before taking up the next topic, Mr. Chairman, I would like to state that at the last annual meeting the new constitution was submitted for adoption by the members present, and as a majority of the society was not present the Board of Managers was instructed to submit it to the members for a letter vote. Such a vote has been taken and returned to the Board of Managers, unanimously adopting the new constitution. According to the resolution of the annual meeting this constitution, copies of which have been distributed to the members, becomes operative from to-day, with the exception that no change in the officers takes effect at this time.

The next topic is: "What is a safe velocity for steam to travel in steam mains and risers? Is a half inch radiator valve large enough on a steam supply to small radiators?"

The topic was discussed by Prof. Carpenter, Messrs. A. G. Paul, Warren Webster and D. M. Quay.

The session then adjourned.

## SESSION OF JULY 22.

The meeting was called to order on Saturday, July 22d, at 10.55 A. M., by First Vice-President Quay.

The Chairman: The first thing on the programme this morning is a discussion. The secretary will please read the topic. I am pleased to see that we have with us this morning Mr. Barrell, from Cambridge, Mass., and Mr. Hart, of Hart & Crouse. We are pleased to welcome them to the meeting and will be glad to hear from them.

Secretary Mackay: The topic is: "What is the relative fuel economy of heating with steam or hot water of low pressure and temperatures?"

The topic was discussed by Messrs. Paul, Wolfe, Adams, Webster, Secretary Mackay and Profs. Kinealy and Carpenter.

During the discussion a motion, made by Mr. W. F. Wolfe and seconded by Prof. Carpenter, was carried, requesting the Committee on Tests to gather such data as possible in connection with the topic and report them to the Society.

The Chairman: The next in order will be the report of the School House Committee. This was presented at the annual meeting in January and ordered printed for discussion at the semi-annual meeting. I suppose it is hardly necessary to read this paper, but I understand it is brought before us for discussion. You all have printed copies, and in order to save time it might be well to dispense with the reading of it.

Mr. Wolfe: If my memory serves me correctly, Mr. Chairman, this was read at the annual meeting, and in view of the fact that so few reports had been received in proportion to the large number expected, it was hoped that several more of the committee would add their reports to this, so that at this meeting we would have further data than we had at that time. But I do not recognize anything here excepting what we had before.

The Chairman: I find that Mr. Nesbit's paper is virtually in the same line, on the same topic or largely so, and I think we will have Mr. Nesbit's paper read and then take up the discussion of the two papers.

Mr. Wolfe read the paper by Mr. D. M. Nesbit on Warming and Ventilation of Schools in England.

The Chairman: At this time I would appoint the committee of two to act with Mr. Jellett on the relation of the architect to the engineer as suggested in his paper and as decided by our meeting last evening. I appoint Prof. R. C. Carpenter and Mr. Adams, our President, on this committee.

We will now hear any discussion that there may be on Mr. Nesbit's paper, and also on the report of the School Committee.

Prof. Carpenter: I think we owe a vote of thanks to Mr. Nesbit for the very excellent paper and the very full description of buildings he has given us. Mr. Nesbit, in preparing this paper, has been to considerably more trouble than any of our members in this country and has done most admirable work. As a rule I do not believe in

votes of thanks, but when a foreign member takes such interest in our society as he has done, I think a vote of thanks is called for. I therefore move that the society return a vote of thanks to Mr. Nesbit for the reasons that I have mentioned.

The motion was seconded by Mr. Wolfe and carried. Mr. Wolfe made some comments on Mr. Nesbit's paper.

The Chairman: Is there any further discussion on either of these papers, Mr. Nesbit's, and the report of the School House Committee?

Mr. Wolfe: I would move that the committee be continued and that further reports be requested from the members not having made reports. (Seconded and carried.)

A recess of a few minutes was then taken.

The Chairman: The meeting will please come to order. We will now hear the report of the Paris Exhibit Committee. Is the committee ready to report?

Prof. Kinealy read the report of the committee, as follows:

REPORT OF PARIS EXPOSITION CONFERENCE COMMITTEE.

Mr. President and Members:—Your committee appointed to confer with and aid Mr. Wiltsie Fuller Wolfe, expert in the department of varied industries for the Commissioner General of the United States to the Paris Exposition of 1900, have entered upon their duties and have submitted the following letter to Mr. Wolfe:

"Dear Sir:—We, the undersigned, have been appointed as a Committee of the American Society of Heating and Ventilating Engineers, to confer with and aid you in your work in connection with the Paris Exposition of 1900.

"In your communication to the Society we note that you ask especially for suggestions as to the general prominence that shall be given to the various exhibits of apparatus and processes for heating and ventilating. As we consider this a question which should receive prompt attention, we desire to say that after having carefully considered the subject, and the space available, we respectfully suggest that this space be apportioned as follows:

"To stoves and ranges, heating and cooling, for all kinds of fuel, 25%; to hot-air furnaces and the appliances and appendages that go with them, 10%; to steam and hot-water boilers for house heating, together with the appendages and appliances which go with them, 20%; to radiators, thermostats, valves, air valves, etc., 25%; to fans and blowers, 10%; to showcases for small miscellaneous apparatus, such as thermometers, anemometers, pyrometers, etc., 10%. These

apportionments are based on the assumption that after the space for aisles and walks is taken out there will remain about 1,000 square feet of floor space to be utilized for exhibiting the various appliances. We suggest that the entire wall space available be used for the display of plans, diagrams and charts illustrating different systems of heating and ventilation and the construction of such apparatus as may properly be included in the exhibition under your supervision.

"The committee heartily approve the plan outlined by you, and feel that the suggestions made here are but a small part of their work and wish to assure you that it will gladly confer with you and lend any further assistance possible at any time you may desire.

"Very respectfully,

"J. H. KINEALY,
"R. C. CARPENTER,
"FRANK K. CHEW,
"Committee."

On motion of Mr. Paul the report was received and the committee continued.

Mr. Wolfe: Mr. Chairman and gentlemen of the society, on behalf of the commission and personally, I wish to thank the society and its committee for its very kind suggestions and to assure you that it will be of much help to us.

The Chairman: Is there anything further to come before the meeting?

Prof. Kinealy: I would like to make a motion before we adjourn. In, I think, almost all societies other than this one, it is customary, when a man reads a paper before the society, to submit to him all of the discussion in order that he may close the discussion. I believe that is not done here, but it should be done. The man who reads the paper should close the discussion. Oftentimes through the misuse of a word, through an error, a man may say in a paper what he did not exactly mean, or he may not make his meaning clear, and then in the discussion a false view of his statement would be taken. Now he should have the right to answer that discussion and make his meaning clear. I therefore move that all the papers which have——

Prof. Carpenter: That is out of order. That has already been done.

The Chairman: That is a rule, I understand, of the society.

Secretary Mackay: That is right; it is a by-law. I would like to state that the reason why that was not done last year, was because Mr. Jellett, our former secretary, could not de-

vote time to the book and he turned it over to one of our members who volunteered to arrange for it. He did not complete it and turned it over to the editor whom we have since employed, and he, on the assumption that all of that had already been done, rushed it into the printer's hands and got it out without submitting it to some of our members. I have had complaints from two or three of our members on the subject. Mr. Paul and others have mentioned that certain things they are put down as having said are wrong. I can say that as we have a permanent editor now, such transgressions of the by-laws will not occur in the future.

On motion the meeting then adjourned.

# PAPERS

OF THE

# SARATOGA MEETING,

July 21 and 22, 1899.

## LXI.

# THE CALCULATION OF CENTRIFUGAL FANS FOR VENTILATING PURPOSES.

BY H. EISERT.
(Member of the Society.)

Since the more general introduction of centrifugal fans (blower type) for the ventilation of buildings in recent years, the interesting subject, "Fans, etc.," has repeatedly occupied prominent space in the columns of our technical papers, and has also been exhaustively treated by recognized authorities in separate publications.

Though the present status of the subject can not be considered as final, the conclusions arrived at thus far can be accepted as such with perfect safety.

Among the best publications on this subject are, scientifically most important, "Murgue's Treatise on Fans for Mine Ventilation" (a French work), and two treatises by Prof. Lindner: "Theory of Centrifugal Pumps,"* and "The Irregular Movement of the Air in Centrifugal Fans." Both treatises were published through the Society of German Engineers.

Of the other publications on the same subject few give the conclusions in a sufficiently convenient and reliable form for practical application; while still others resort to empirical and sometimes even rather arbitrary rules.

Murgue's theory is chiefly based on fans used for mine ventilation. This assertion is borne out by the fact that Murgue's conclusions all contain a certain value, the *orifice equivalent*, which, though easily determinable for mines, is of too relative a nature to be used with advantage for the calculation of fans of the blower type, such as are now generally used for the ventilation of buildings.

Professor Lindner's treatises, on the other hand, are very exhaustive, giving a true picture of the performance of fans of various constructions under working conditions. Most of his conclusions, however, are novel, in so far as their development deviates some-

*Translated by Passed Asst. Eng. Theiss and published in Proc. of Soc. of Naval Engineers, several years ago.

what from the conventional methods. So, for instance, Professor Lindner shows that the pressure head produced by a revolving fan wheel can be expressed by:

$$H = \frac{(\omega + \vartheta)\vartheta}{2g} (r_o^2 - r_i^2) \quad \ldots\ldots 1.$$

when $\omega$ = the angular velocity of the blades,
$\vartheta$ = " " " " air,
$r_o$ = " outer radius of fan wheel,
$r_i$ = " inner " " " at inlet.

For fans with radial blades, when it can be assumed that $\omega = \vartheta$ equation 1 is modified to $H = \frac{\omega^2}{g} (r_o^2 - r_i^2)$ and, as

$$r.\ \omega = u = \frac{d.\pi.n}{60},$$

that is the peripheral velocity of the fan tips, furthermore to

$$H = \frac{u^2}{g} \left(1 - \frac{r_i^2}{r_o^2}\right) \quad \ldots\ldots 2.$$

which, for $\frac{r_i}{r_o} = \sqrt{\frac{1}{2}}$ assumes the form:

$$H = \frac{u^2}{2g} \quad \ldots\ldots 2^a.$$

The validity of Prof. R. C. Carpenter's formula:

$$h = 0.667 \frac{v^2}{g}$$

as proposed in his "Theory of Centrifugal Fans,"* would thus be limited to fan wheels with straight blades having a ratio

$$\frac{r_i}{r_o} = \sqrt{1 - 0.667} = 0.578.$$

The value of equation 1, however, differs materially for fans with curved blades, because of the difference between the relative peripheral velocity of the blades a and that of the moved air $\vartheta$. This difference is expressed by the relation:

$$w - \vartheta = \omega \frac{tg\varepsilon}{r} \quad \ldots\ldots 3.$$

where w is the radial velocity of the air at the fan tips, and $\frac{tg\varepsilon}{r}$ a coefficient representing the curvature of the fan blade. By introducing

*"Heating and Ventilation," December 15, 1894, page 4.

for $s$ its value from equation 3, into equation 1, the latter becomes

$$H = \frac{(2w - \omega \frac{tg\varepsilon}{r})(w - \omega \frac{tg\varepsilon}{r})}{2g} (r_o^2 - r_i^2)$$

and, when modified:

$$H = \frac{u^2}{2g} \left[1 - \frac{r_i^2}{r_o^2}\right] \left[2 - \frac{w}{\omega} \frac{tg\varepsilon}{r}\right] \left[1 - \frac{w}{\omega} \frac{tg\varepsilon}{r}\right] \quad \ldots\ldots 4.$$

This form shows plainly that, though having other decided advantages, fans with curved blades require a higher peripheral velocity in order to create a certain pressure H, unless it is counteracted by a reduction of the proportion $\frac{r_i}{r_o}$ that is, by increasing the length of the blades. The latter statement is fully corroborated by the general practice of proportioning the main features of fans. Usually the fans for ventilating purposes are built with short radial blades and correspondingly large inlets, while the pressure blowers have longer blades and smaller inlets. But, notwithstanding that such is generally known and well considered in the practice of fan-building, there are still some formulæ being used for determining the pressure produced by a fan wheel, wherein the effect of the length and form of the fan blades is not taken into account. The actually existing variance of their form must be attributed to the fact that the experiments from which these formulæ have been deducted were probably limited to one fan, and that each experimenter used a fan differently proportioned from the others. The validity of any such formula is, therefore, naturally limited to fans and conditions identical with those of the original experiment.

It must be understood, however, that the pressure heads, as expressed by equations 2 or 4, represent a maximum that can be produced by a fan wheel only under certain conditions. The actual pressure produced in any given case depends mainly upon the area of the fan outlet and the resistance to a free discharge of the air. The more freely the air is discharged the less the pressure that will be produced by a fan. The minimum pressure will be produced when the fan discharges the air free into the atmosphere, in which case the pressure head produced at the fan outlet is solely due to the velocity v of the passing air, and therefore determinable by the well-known equation for falling bodies, viz.:

$$H = \frac{v^2}{2g} \quad \ldots\ldots 5.$$

This pressure will necessarily increase as soon as there is any re-

sistance to the flow of the air, and reach its maximum for fans with radial blades, when $\frac{v^2}{2g}(1+x) = \frac{u^2}{g}\left(1 - \frac{r_i^2}{r_o^2}\right)$

and for fans with curved blades when

$$\frac{v^2}{2g}(1+x) = \frac{u^2}{2g}\left(1 - \frac{r_i^2}{r_o^2}\right)\left(2 - \frac{w}{\omega}\frac{tg\varepsilon}{r}\right)\left(1 - \frac{w}{\omega}\frac{tg\varepsilon}{r}\right)$$

Any increase of the resistance, x, would only tend to reduce the velocity v of the discharged air, even to $v = o$, in which case the pressure head produced by the fan wheel equals the existing resistance head and absolutely no air will be discharged; a condition that is analogous to a closed fan outlet.

The ratio of the actually produced pressure at the fan outlet to the maximum ideal pressure produced by the fan wheel at the same number of revolutions can be termed the *manometric efficiency* of the fan.

In equation 5, the pressure head H is expressed as the height of a column of air in feet. In practice, however, it is customary to express the pressure of air in inches of water, as indicated by the balanced height P inches of a column of that liquid in a water gauge. This may be readily transformed into the height in feet of a column of air by the relation:

$$H = \frac{P}{12}\frac{\text{density of water}}{\text{density of air}}$$

or with the corresponding values introduced by:

$$H = 64.636\ P\ [1 + \alpha\ (t - 32)] \quad \ldots\ldots 6.$$

By combination of equations 5 and 6, follows:

$$P = 0.00024\ V^2\ \frac{1}{1 + \alpha\ (t - 32)} \quad \ldots\ldots 7.$$

and, by further transformation:

$$V = 64.477\ \sqrt{P\ [1 + \alpha\ (t - 32)]} \quad \ldots\ldots 8.$$

When ascertaining the velocity, V, it must be considered that a stream of any fluid escaping through an orifice is concentrated just beyond the opening, and that the extent of this contraction varies mainly with the character of the orifice; but in case of air, also somewhat with the area of the orifice and the ratio of the pressure difference. While the contraction of the stream of air is greatest when passing through an orifice in a thin plate, a continuation of such orifice in the form of a pipe or duct serves to reduce it. The

ratio of this contraction is commonly represented by the coefficient of efflux c.

Exhaustive experiments to this effect have shown that the value of c, when the difference in the pressures of the air is comparatively small, as in the case of a fan, may be taken as follows:

| | |
|---|---|
| For an orifice in thin plate (fan inlet) | = 0.56 |
| For a short pipe or duct (fan outlet) | = 0.75 |
| For a rounded-off conical mouth-piece | = 0.98 |
| For a conical pipe whose angle of convergence is about 6° | = 0.92 |

As thus only c.F of the cross area F of an opening can be considered as effective for the passage of the air, the velocity V at which Q cubic feet of air, delivered by a fan in one minute, pass its outlet of the cross area F square inches is determined by:

$$V = \frac{60\,Q}{25.\,c.\,F.} = \frac{2.4}{c} \cdot \frac{Q}{F} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 9.$$

feet per second.

Under working conditions it is expected that a fan will deliver Q cubic feet of air against a pressure $p_r$, the equivalent in inches of water of all resistances to the flow of the air in all sections of the apparatus from fresh air intake to the air outlets in the rooms, and, in case a plenum condition is to be created in the rooms, even to the end of the foul air duct system. In most cases, however, the resistance in the latter is not taken into account for the air supply system, especially when exhaust fans are used.

Researches by Professor Rietschel and others have shown that the resistance to the flow of air in ducts is proportional to the square of the velocity of the passing air, while the resistance offered by air filters increases only with the volume of the air to be filtered. As to the resistance to be overcome by the air passing through pipe coil heaters or cast iron sectional heaters, no authentic data are obtainable, and it is very deplorable that so little attention is paid to this subject when experiments and tests are made. But, judging by the nature of the offered passage to the flow of the air through the heater, it can be safely assumed that the resistance increases with the *square* of the velocity of the passing air.

Under all considerations, it is difficult to determine the exact value of $p_r$ by calculation, and in few cases, if at all, an attempt to that effect will be made. Approximate calculation based on data obtained from experience and observation in similar cases will often have to be relied upon.

The following equivalents in inches of water for the resistances in various sections of the apparatus will answer in most cases for all practical purposes:

In the duct system from heater to rooms,

$$p_d = \tfrac{1}{4} \text{ to } \tfrac{1}{3} \left(\tfrac{v}{1000}\right)^2$$

in a pipe coil heater "m" pipes deep,

$$p_h = \tfrac{1}{1000} \text{ to } \tfrac{1}{800} \text{ m } \left(\tfrac{v}{1000}\right)^2;$$

in an air filter,

$$p_h = \tfrac{1}{300} \text{ to } \tfrac{1}{150} \text{ v};$$

and for all other conditions that tend to increase the resistance to the flow of the air, in due proportion. In each case, however, v represents the maximum velocity of the air in that section. Thus, in order to deliver Q cubic feet of air at a velocity v against a resistance head in the apparatus equivalent to p inches of water, the fan wheel must produce a pressure $p_o$ at the fan outlet equal to the velocity head of the air at that point plus the resistance head in the apparatus, viz.:

$$p_o = p_v + p_r \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 10$$

Of this, the velocity head $p_v$ or that part of the total presssure $p_o$ which is utilized in creating the velocity v of the air at the fan outlet, is always determinable by equation 7, viz.:

$$p_v = 0.00024 \frac{v^2}{1 + \alpha(t - 32)},$$

while the resistance head, or the part which is expended in overcoming the resistance in the apparatus, is given by the existing conditions, and may be either ascertained by calculation or assumed from practical experience.

Equation 8 states now that for any pressure produced by a fan at its outlet there is a corresponding velocity at which the air will be delivered *at free discharge*. For the pressure $p_o$ this velocity being:

$$v_o = 64.477 \sqrt{0.00024\, v^2 + p_r [1 + \alpha(t - 32)]}, \quad \ldots\ldots\ldots 11$$

the quantity of air that would be thus delivered per minute is at once determinable by equation 9, viz.:

$$Q_o = \frac{c.F.v_o}{2.4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 12.$$

and as such represents the *nominal capacity* of the fan under the given conditions.

This quantity of air $Q_o$ will be delivered when the fan wheel is run at the rate of:

$$n = \frac{Q_o}{q} \quad \ldots\ldots 13.$$

revolutions per minute.

The quantity q represents the *delivering capacity* of any fan of the blower type, and can be expressed with sufficient accuracy for all practical purposes by a function of the cube of the fan wheel diameter, viz.:

$$q = ed^3 \quad \ldots\ldots 14.$$

that is, a fan of d feet diameter will deliver q cubic feet of air per revolution at *free discharge*.

The co-efficient e naturally varies with the proportioning of the various parts of the fan and its housing. Its value increases slightly, though not directly proportionately, with the width of the fan wheel, but more so when the fan is provided with double inlets. The effect of the area of the fan outlet upon the value e may be neglected as insignificant, but only when the fan is to deliver under such light pressures as required for ventilating purposes. For fan wheels of the same make and class, because of the proportionality of their dimensions at the various diameters, the co-efficient e is nearly constant. Thus, the capacities per revolution of two fans of the same make and class, it can be assumed, bear the relation:

$$\frac{q_1}{q} = \frac{ed_1^3}{ed^3} = \frac{d_1^3}{d^3}$$

The exact value of e for any fan wheel, however, is determinable only by actual experiment.

For single inlet fans of the class used for ventilating purposes, $e = 0.41$ is a good average, and at that corresponds almost identically with that for fans of this class built by one of the foremost fan manufacturing concerns in this country.

For the sake of making equation 12 more adaptable for the greatly varying conditions presented by ventilating plants, a further development of its form becomes necessary. By introducing into equation 12, for $v_o$ its value from equation 11, the former becomes:

$$Q_o = 26.865 \text{ c. F. } \sqrt{0.00024\, v^2 + p_r\,[1 + \alpha\,(t - 32)]} \quad \ldots\ldots 15.$$

This equation still contains two quantities, F and v, which are dependent upon each other, but as, by reason of equation 9, one is a distinct function of the other, either can be readily eliminated. Thus,

by substituting for v its value from equation 9, the equation 15 can be transformed into:

$$Q_o = 26.865\ c.F.\sqrt{0.00024\left(\frac{2.4}{c}\cdot\frac{Q}{F}\right)^2 + p_r\left(1+\alpha\,(t-32)\right)}$$

and by further development, into:

$$Q_o^2 = Q^2 + 721.77\ p_r.c^2.F^2\left(1+\alpha\,(t-32)\right) \quad \ldots\ldots\ldots 16$$

Equation 16 not only shows conclusively the effect of the outlet area "F" upon the required nominal capacity "$Q_o$" of a fan, when an actual quantity of air Q is to be delivered against a resistance equivalent to $p_r$ inches of water, but can also be considered as the fundamental equation for the calculation of the duty of a centrifugal fan when part of a ventilating apparatus.

Equation 16, however, though not in a convenient form, so desirable for practical application, contains the following distinct relations, viz.:

$$Q_o = n.q = 10000\sqrt{\left(\frac{Q}{10000}\right)^2 + \gamma\cdot p_r\left(\frac{F}{1000}\right)^2} \quad \ldots\ldots\ldots 17.$$

$$n = \frac{Q_o}{q} = \frac{10000}{q}\sqrt{\left(\frac{Q}{10000}\right)^2 + \gamma\cdot p_r\left(\frac{F}{1000}\right)^2} \quad \ldots\ldots\ldots 18.$$

$$F = 1000\sqrt{\frac{\left(\frac{Q_o}{10000}\right)^2 - \left(\frac{Q}{10000}\right)^2}{\gamma\cdot p_r}} \quad \ldots\ldots\ldots 19.$$

$$p_r = \frac{\left(\frac{Q_o}{10000}\right)^2 - \left(\frac{Q}{10000}\right)^2}{\gamma\cdot\left(\frac{F}{1000}\right)^2} \quad \ldots\ldots\ldots 20.$$

$$Q = 10000\sqrt{\left(\frac{Q_o}{10000}\right)^2 - \gamma\cdot p_r\left(\frac{F}{1000}\right)^2} \quad \ldots\ldots\ldots 21.$$

when $\gamma = \frac{721.77}{100}\,c^2\left(1+\alpha\,(t-32)\right)$ which, for the average conditions: $c = 0.75$ and $t = +40°$ F. becomes : $\gamma = 4.13$.

Equations 17 to 21 cover the various conditions under which the duty of a centrifugal fan for ventilating purposes can possibly be calculated. These equations also seem to furnish an explanation of the cause, when at a stated number of revolutions, a fan failed to deliver a stipulated quantity of air. In most cases of this nature the outlet area was so large that the created velocity of the air at the outlet was not sufficiently high to prevent a certain "back-lash" of the air. This is corroborated by the fact that in some instances the trouble has been remedied by a corresponding reduction of the out-

let area. Of course, such reductions of the outlet area can be made only within certain limits, as any excess must necessarily have an unfavorable effect on the delivering capacity q of the fan, by reducing the value of the co-efficient e.

The minimum area of a fan outlet would be that, which allows the air, when delivered at free discharge, to pass at a velocity corresponding to the pressure produced by the fan wheel. This condition can be illustrated for fan wheels with straight radial plates by the equation:

$$\frac{u^2}{g}\left(1-\frac{r_1^2}{r_0^2}\right)=\frac{v^2}{2g}$$

by reason of which it is

$$v=u\sqrt{2\left[1-\frac{r_1^2}{r_0^2}\right]}$$

With the corresponding values for u and v substituted, then also:

$$\frac{2.4.n.q}{c.F}=\frac{d.\pi.n}{60}\sqrt{2\left[1-\frac{r_1^2}{r_0^2}\right]}$$

from which follows that:

$$F=144\,\frac{q.}{c.d.\pi}\cdot\frac{1}{\sqrt{2\left[1-\frac{r_1^2}{r_0^2}\right]}}\text{ square inches, or}$$

$$=\frac{q}{c.d.\pi}\cdot\frac{1}{\sqrt{2\left[1-\frac{r_1^2}{r_0^2}\right]}}\text{ square feet.}$$

For a fan with blades proportioned according to the ratio $\frac{r_1}{r_0}=\sqrt{\frac{1}{2}}$ and a delivering capacity $q=0.41d^3$, the minimum area of the outlet would, with $c=0.75$, thus be:

$$F=\frac{0.41\,d^3}{0.75\,d\pi}=0.17\,d^2\text{ square feet,}$$

or about $\frac{1}{6}d^2$ square feet, which for an opening $\frac{1}{2}d$ feet wide would indicate a height of $\frac{1}{3}d$ feet.

The effective work done by the fan under these conditions is equivalent to lifting Q cubic feet of air in one minute to a height equal to the pressure head to be produced at the fan outlet, viz.:

$$H_0=\frac{v_0^2}{2g}$$

and can be expressed by:

$$W=\frac{Q.w.v_0^2}{2g}$$

in foot-pounds per minute, when w is the weight of one cubic foot

of air: or, as 33,000 foot-pounds per minute are considered to constitute one horse power, also by

$$HP_e = \frac{Q \cdot w \cdot v_e^2}{2g \cdot 33000}$$

The actual work done by the fan, however, is greater, because of the energy consumed in moving the fan wheel itself, as well as by the friction in the bearings, etc. The ratio of the effective to the actual work done represents the mechanical efficiency of the fan ($\eta_t$), and usually ranges from $\eta_t = 0.40$ to 0.75. (The mechanical efficiency of fans for ventilating purposes averages about $\eta_t = 0.5$.) Thus, the power to be actually transmitted to the fan shaft must not be less than:

$$HP_a = \frac{1}{\eta_t} \quad HP_e = \frac{Q \cdot w \cdot v_e^2}{\eta_t \, 2 \cdot g \cdot 33000} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 22.$$

Substituting now for $v_e$ its value from equations 12, and for the weight of one cubic foot of air at the temperature $t = +40°$, the value $w = 0.08$ pounds, equation 22 can be transformed into:

$$HP_a = \frac{0.08 \, Q_e}{\eta_t \, 2g \cdot 33000} \left( \frac{2.4}{c} \frac{Q}{F} \right)^2$$

which for $c = 0.75$, and with $Q = nq$ becomes:

$$HP_a = \frac{1}{\eta_t} \, 38.6 \left( \frac{q}{F} \right)^3 \frac{Q}{10000} \left( \frac{n}{100} \right)^2 \quad \ldots\ldots\ldots\ldots 23.$$

The factor $\frac{1}{\eta_t} 38.6 \left( \frac{q}{F} \right)^3$ is a constant for each fan, and being a function of its outlet area, capacity, and mechanical efficiency, can be determined beforehand for fans of various sizes and the results arranged in tabulated form for ready use. In case of a necessary reduction of the original outlet area from F to $F_1$, this factor must be corrected accordingly. Equation 21, also shows the unfavorable effect of any reduction of the outlet upon the necessary power to drive the fan, which increases at the ratio $\left( \frac{F}{F_1} \right)^3$

In practice, however, it is customary to provide for the fan a motor of sufficient capacity to drive the fan at an increased rate of speed should the occasion arise for a greater air supply. From equation 23 follows that the power necessary to drive a fan is proportional to the cube of the delivered quantity of air, since Q must be consid-

ered as a function of $Q^1$, and vice versa; a condition that can be expressed by the following relation, viz.:

$$\frac{HP_a^1}{HP_a} = \left(\frac{Q^1}{Q}\right)^3 = \rho$$

Calculated values of "$\rho$" for various proportions are given in the following table:

| $\frac{Q^1}{Q}$ = | 1.05 | 1.10 | 1.15 | 1.20 | 1.25 | 1.33 |
|---|---|---|---|---|---|---|
| $\rho$ = | 1.15 | 1.33 | 1.15 | 1.75 | 1.95 | 2.35 |

A further allowance must be made when the power is transmitted from motor to fan shaft by belting. This allowance, however, varies with the diameter of the fan wheel, and may be taken for:

| d = | 5 | 7 | 7 | 8 | 9 | 10 | feet. |
|---|---|---|---|---|---|---|---|
| $\varphi$ = | 0.0038 | 0.0062 | 0.0097 | 0.0146 | 0.0212 | 0.03 | H.P. per revolution. |

For crossed belts the coefficient $\varphi$ must be increased 25%. The diameter of the pulley on the fan shaft should be made about 1/5 to 1/4d., and from 1/8 to 1/7d. its width.

The required capacity of the motor can now finally be selected by the equation:

$$HP_1 = \frac{\rho}{\eta_1}(HP_a + \varphi n) \qquad 24.$$

The *mechanical efficiency* of the motor $\eta_1$ ranges from 1/2 to 2/3 for steam engines of the size and class usually furnished with fans of this class; for electric motors is $\eta_1$ about $\frac{3}{4}$ when directly attached to the fan shaft.

In concluding, a few remarks relating to the practical application of equations 17, 18 and 19 may be added. As the pressure necessary to create a certain velocity increases with the *square* of the velocity, it is desirable to limit the velocity of the air on leaving the fan outlet as much as possible. But, at the same time, it must be considered that with a reduced velocity of the air discharging against a resistance the unavoidable "back lash" of the air is increased, and that this "back lash" still further increases with the resistance. This condition is plainly illustrated by equation 18, which shows that the number of revolutions at which a fan of the delivering capacity q must be run in order to deliver a stipulated quantity Q of the air, increases with the resistance *and* with the area of the outlet opening. On the other hand, again, a reduced outlet area will increase the power necessary to drive the fan, since by equation 10 an increased

velocity of the air increases also the pressure that must be produced by the fan at the outlet opening.

This increase of the motive power, however, is to a certain extent counteracted by the reduction of the necessary number of revolutions. The latter condition is illustrated by equations 18 and 23.

Investigations of various tests and comparative calculations seem to show that the best results are probably obtained when the necessary velocity head of the air is nearly as high as the resistance head in the apparatus. This, however, is rarely possible for higher resistances with fans of the usual commercial proportions, and that solely because of their fixed outlet areas.

Fans with large outlets give satisfactory results only when delivering against very low resistances, as in the case of ventilating plants, and even then the *mean* velocity of the air on leaving the fan outlet should not be less than about 24 feet per second. This condition creates the relation:

$$F \leq \frac{Q \cdot 2.4}{24} = \frac{Q}{10} \text{ approximately,}$$

that is, the size of the fan should be selected so that its outlet will pass at least 10 cubic feet of air in one minute per square inch of its gross area. Having thus tentatively decided upon the size of the fan, its oulet area F and its delivering capacity q are known at once. The required nominal capacity of the fan, in cubic feet of air per minute at free discharge, is then determinable by equation 17, and by equation 18, the necessary number of revolutions n at which the fan is to be run. Should it now occur that the number of revolutions n, under the assumed condition, is so great that the corresponding circumferential velocity of the fan tips exceeds a certain limit, (which for ventilating purposes should always be less than eighty feet per second,) then the number of revolutions is to be fixed beforehand, and the required outlet area determined by equation 21. But whenever under the existing condition the necessary reduction of the outlet area becomes too excessive, another size of fan must be selected; for extreme conditions even fan wheels with longer blades, that is, such with a reduced ratio $\frac{r_1}{r_0}$, may become necessary. Owing to a lack of reliable data as to the delivering capacities, etc., of pressure blowers, this class of fans will not be further considered here.

In all cases, however, it is advisable to provide every fan with an adjusting arrangement, by means of which its outlet area can be

regulated within certain limits to suit the actually existing conditions, which often deviate more or less from those assumed or otherwise determined for the calculation of the fan duty. The following examples are appended to still further illustrate the practical application of the foregoing conclusions. The first example will be based upon data furnished by Prof. R. C. Carpenter in his "Theory of the Centrifugal Fan or Blower"*:

Diameter of fan wheel: $d = 84$ inches $= 7$ ft.
Width at center: 36 "
Diameter of inlet: $d_1 = 54$ "
Outlet opening: $F = 40 \times 42 = 1{,}680$ sq in.
Actually delivered volume of air: $Q = 21{,}000$ cu. ft. per minute.
Number of revolutions: $n = 220$.
$HP_a$, delivered at fan: $= 5.5$
$HP_1$ of engine $= 8.6$

By the stated fan proportions it can be assumed that the blades bear a ratio of not more than $\frac{r_1}{r_0} = 0.643$, and are most likely radial and straight. The maximum pressure head produced by the fan wheel at 220 revolutions per minute, which corresponds to a circumferential velocity of $u = \frac{d.\pi.n}{60} = 80\frac{2}{3}$ feet per second is, therefore, probably $H = \frac{u^2}{g}\left(1 - \frac{r_1^2}{r_0^2}\right) = 0.587\,\frac{u^2}{g}$ feet.

The equivalent of this pressure head at $t = +34°F$, is

$P = 1.74$ inches of water, or
$= 1.007$ ounces per square inch.

Under the same conditions, the stated pressure of $\frac{7}{8}$ ounces per square inch, would indicate a ratio of about $\frac{r_1}{r_0} = 0.7$, and at that is identical with the maximum pressure produced by B. F. Sturtevant Co.'s fan wheel 7 feet in diameter, as given in their catalogue No. 96, page 110.

As now for the fan outlet, the coefficient of contraction for the passing air can not be taken higher than $c = 0.75$, the actually delivered quantity of air, $Q = 21{,}000$ cubic feet per minute, passes the fan outlet at the actual velocity: $v = \frac{Q.2.4}{c.F} = 40$ feet per second,

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and for that purpose requires at the temperature $t = 34^\circ$ F., a velocity head equivalent to

$$P_v = 0.00024 \frac{v^2}{1 + \alpha (t - 32)} = 0.384 \text{ inches of water.}$$

Judging further from the proportions of the fan, which is rather narrower than usual at that diameter, its delivering capacity will not exceed $q = 0.4d^3 = 137$ cubic feet per revolution, or for the stated number of revolutions: $Q_0 = nq = 220 \times 137 = 30{,}140$ cubic feet per minute at free discharge.

The resistance to the flow of air in the apparatus is now determinable by equation 20, and amounts to not more than

$$p_r = \frac{\overline{3.014}^2 - \overline{2.1}^2}{4.13 \times \overline{1.680}^3} = 0.401 \text{ inches of water.}$$

The actually produced pressure of the air at the fan outlet is, therefore: $p_0 = p_v + p_r = 0.384 + 0.401 = 0.785$ inches of water, indicating that the monometric efficiency of the fan is about:

$$\frac{0.785}{1.74} = 0.452.$$

The actual work done by the fan was found to equal 5.5 horse power, and as by equation 24,

$$5.5 = \frac{1^2}{\eta_t} 38.6 \left(\frac{q}{F}\right)^2 \cdot \frac{Q}{10000} \left(\frac{n}{100}\right)^2 = \frac{2.54}{\eta_t} \text{ HP}_e$$

the mechanical efficiency of the fan therefore:

$$\eta_1 = \frac{2.54}{5.5} = 0.53.$$

The efficiency of the driving steam engine amounts to:

$$\eta_1 = \frac{5.5}{8.6} = 0.64.$$

As a second example may serve the analysis of the test of a fan with direct connected engine constructed by Messrs. Bumstead & Chandler, of Hednesford, England, for a vessel of the Hamburg-American line. The data, as taken from "The Engineering Record" (Vol. 39, No. 23, May 6, '99), are as follows:

Fan diameter: $d = 78$ inches.

Chocked fan outlet: $8\frac{1}{8}$ inches by $25\frac{1}{4}$ inches; $F = 205$ square inches.

Delivery: $Q = 13{,}978$ cubic feet per minute.

Number of revolutions: $n = 400$ per minute.

Pressure: $P = 6\frac{1}{8}$ inches of water.

Indicated horse power of engine: $HP_i = 21.03$.

No reference is made to the form of the blades, neither are the diameters of the double inlets given.

Assuming now that the usual routine was followed in making the test, the pressure was either measured direct or, more likely, calculated from the measured velocity of the air at the fan outlet.

The velocity corresponding to a pressure of $6\frac{1}{8}$ inches of water is determined by equation 9, being:

$$V = 64.477 \sqrt{p \left[ 1 + \alpha (t - 32) \right]} = 163.6 \text{ feet per second,}$$

at once shows that the above stated quantity of 13,978 cubic feet of air could be discharged only under its own velocity head and against *no* resistance; that is, free into the atmosphere, as:

$$13{,}978 = \frac{163.6 \times 205}{2.4} ,$$

provided there was no contraction of the air at the fan outlet. This however, is very doubtful, and especially so in this case. Granting now a coefficient of contraction as high as $c = 0.75$, which most likely was not reached, owing to the excessively choked outlet opening, the maximum delivery was probably not more than

$$Q = \frac{v.\ c.F}{2\ 4} = 10{,}484 \text{ cubic feet per minute,}$$

which would indicate a delivering capacity of the fan equal to

$$\frac{Q}{n} = q = \frac{10.484}{400} = 26.21$$

cubic feet per revolution, and correspond to $q = 0.095 d^3$.

The actual work done by the fan, as determined by equation 23, amounts to:

$$\frac{1}{\eta_t} 38.6 \left(\frac{q}{F}\right)^2 1.0484. (4)^2 = \frac{10.57}{\eta_t} HP_e$$

and, as the indicated horse power of the engine was found to be 21.04, the combined efficiency of engine and fan, therefore,

$$\eta_i \eta_t = \frac{10.57}{21.04} = 0.5$$

The latter value seems to be more feasible than the stated efficiency 0.64, as 0.6 could be allotted to the fan and about 0.83 to the engine, though exceptionally high values at that, while in the other case the efficiencies of fan and engine would appear unreasonably high.

The absence of the necessary data forbids any further conclusions as to the manometric and volumetric efficiency of this fan under actual working conditions.

The third and last example will show the practical application of the foregoing conclusions in the calculation of the required size and duty of a fan for ventilating purposes.

15,000 cubic feet of air per minute are to be actually delivered into a system of ducts against a probable resistance equivalent to $\frac{1}{4}$" water pressure, but for certain reasons it is desirable that the *mean* velocity of the air at the fan outlet should not exceed 24 feet per second.

The latter condition determines at once, that the gross area of the fan outlet must be not less than $\frac{Q}{10} = 1{,}500$ sq. inches. Selecting a B. F. Sturtevant Co.'s fan of the size 6x9, having an outlet 42"x42", the area equals F = 1,764 square inches. If now the character of the opening and its effect upon the discharge of the air is represented by the coefficient of efflux c = 0.75, and the delivering capacity of the fan by $q = 0.41d^3 = 88.56$, or 90 cubic feet per revolution at free discharge, the necessary number of revolutions at which the fan wheel must be run is found by equation 18, viz.:

$$n = \frac{10{,}000}{90}\sqrt{(1.5)^2 + \frac{4.13}{4}(1.764)^2} = 260 \text{ per minute.}$$

The corresponding circumferential velocity thereto being:

$$u = \frac{d.\pi n}{60} = 0.05236 \times 6 \times 260 = 82.0 \text{ feet per second,}$$

and the ratio $\frac{r_1}{r_0}$ for this class of fans very nearly $= \sqrt{\frac{1}{2}}$, the maximum pressure head produced by the fan at 260 revolutions per minute is determinable by equation $2^a$, viz.:

$$H = \frac{u^2}{2g} \text{ feet,}$$

for which can be substituted its equivalent in inches of water:

$$P = 0.00024 \frac{u^2}{1 + a(t - 32)}$$

so that for $t = +40°$ and $u = 82$, finally:

$$P = 1.58 \text{ inches of water, or}$$
$$= 0.916 \text{ ounces per square inch.}$$

The actual pressure produced by the fan at its outlet, however, equals $p_o = p_v + p_r$, when $p_r$ = the equivalent in inches water

pressure of the velocity head of the discharging air, and $p_r = \frac{1}{4}$ inches water pressure, the equivalent of the probable resistance in the apparatus as stated.

The *actual* velocity of the air at the fan outlet is now

$$v = \frac{15000 \times 2.4}{0.75 \times 1764} = 27.21 \text{ feet per second,}$$

and the corresponding velocity head equivalent to:

$$p_v = 0.00024 \frac{(27.21)^2}{1 + \alpha (t - 32)} = 0.185 \text{ inches.}$$

Hence, $p_0 = 0.185 + 0.25 = 0.435$ inches, thus limiting the manometric efficiency of the fan to

$$\eta_m = \frac{0.435}{1.58} = 0.28$$

The necessary power to drive the fan follows from equation 24, viz.:

$$\frac{1}{0.5} 38.6 \left(\frac{90}{1764}\right)^2 1.5 (2.6)^2 = 2.038 \text{ HP}_a$$

In case that for some reason the air supply may be increased 20%, and that the fan be driven by belt from a steam engine, the necessary indicated horse power of the engine should be

$$\frac{1}{0.5} \times 1.75 \times 2.038 + 0.0062 \times 260 = 9.112 \text{ HP}_i$$

If this fan were possible with an adjusting arrangement, by means of which the area of the fan outlet could be reduced to 42"x36", offering only 1,512 square inches for the passage of the air, the actual velocity of the air at the outlet would then be:

$$v = \frac{15,000 \times 2.4}{0.75 \times 1512} = 31.74 \text{ feet per second,}$$

and correspond to a velocity head equivalent to

$$p_v = 0.00024 \frac{(31.74)^2}{1 + \alpha (t - 32)} = 0.254 \text{ inches.}$$

The pressure now produced by the fan at the outlet equals

$$p_0 = 0.254 + 0.25 = 0.504 \text{ inches.}$$

The required number of revolutions under these conditions is:

$$n = \frac{10,000}{90} \sqrt{(1.5)^2 + \frac{4.13}{4} (1.512)^2} = 238 \text{ per minute,}$$

and the corresponding circumferential velocity

$$u = 0.05236 \times 6 \times 238 = 72.5 \text{ feet per second.}$$

At this velocity the maximum pressure produced by the fan wheel equals:

$$p = 0.00024 \frac{\overline{(72.5)^2}}{1 + \alpha\,(t - 32)} = 1.25 \text{ inches,}$$

increasing the manometric efficiency of the fan to

$$\eta_m = \frac{0.504}{1.25} = 0.4$$

The actual motive power required for the fan is now:

$$\frac{1}{0.5} 38.6 \left(\frac{90}{1512}\right)^3 1.5\,(2.38)^2 = 2.35, \text{ HP}_a$$

and under the same conditions as before,

$$\frac{1}{0.5} 1.75 \times 2.35 + 0.0062 \times 238 = 9.6 \text{ HP}_i$$

The volumetric efficiency in this case being

$$\eta_v = \frac{Q}{Q_o} = \frac{15000}{21660} = 0.69, \text{ against}$$

$$\eta'_v = \frac{Q}{Q'_o} = \frac{15,000}{23,400} = 0.65 \text{ in the former case.}$$

DISCUSSION.

Prof. Carpenter: There are some things in this paper to which I would like to call attention in the form of a discussion.

In the first place in regard to formula 1, page 196, which is the beginning of Mr. Eisert's theory, I do not believe in that formula to begin with. I think the formula is wrong, and for that reason I presume I should say that a good deal of the theory that is given here does not agree with my notion at all of running a fan. I have in my paper quite a discussion of the pressure produced by centrifugal fans, and I have also called attention to this theory in that paper, and shown that this theory, which is the old one, is unmistakably in error and that it is not the correct theory at all; we can get with a fan more than fifty per cent. more pressure than this formula makes possible. I can do that with any fan. You can yourselves see what sort of a theory it must be which will fall that much short of possibilities. In other words, if the formula for pressures were true, we could get in the ordinary working of fans a fan with a manometrical efficiency of 150 to 175 per cent. That is not true. The trouble is with the form of the formula which I will speak of in my paper.

On page 197 Mr. Eisert makes a statement which it seems to me should be substantiated by a considerable number of data, although I have no doubt that it is true. But it seems to me that he has assumed a condition without having any very good theory for it—certainly he has not expressed the theory here for it, nor has he given any facts or experiments in regard to the effect which the area of the fan outlet has upon the pressure of the air. There have been a good many data gathered together, but so far as I know there has not been any very good statement of the relation, and he assumes in here, without giving any reason, that certain relations follow.

On page 199 is a statement which I do not think is correct. It is in regard to the resistance offered to the passage of air through pipes. The statement is this—it is in the second paragraph: "Judging by the nature of the offered passage to the flow of the air through the heater, it can be safely assumed that the resistance increases with the square of the velocity of the passing air." Now Mr. Eisert seems not to be familiar with the English experiments that have been made on these subjects. He seems to be more familiar with what the Germans have done. It is a matter of fact that there has been an immense amount of work done by English authorities on this subject, and perhaps no one in the world has done so much on this subject as Prof. Unwin, of London, whose researches are almost classical. The investigation of the friction laws of the flow of air in pipes would serve to show that they follow the same law as water; that is that the friction increases with a quantity which is greater than the square of the velocity of the air, and I think that Mr. Eisert could have given us some data on that subject if he had looked up the experiments that have been made.

On page 201 there is a transition in the paper which I do not understand. I do not see how he can induce it at all from his formula. He makes the statement, following equation 13: "The quantity 'q' represents the delivering capacity of any fan of the blower type, and can be expressed with sufficient accuracy for all practical purposes by a function of the tube of the fan wheel diameter." Now, I do not think there is a single thing in his theory that would permit that. It is a fact that it can be expressed by a function of the fan wheel diameter, simply because fans are built generally in certain fixed ratios so that the width bears some relation to the diameter. This discussion entirely neglects the effect that the width of the fan wheel has on the discharge capacity or the power required to operate it or anything connected with it. The width has a great deal to do with those things. The reason that the statement is true that for all practical

purposes the quantity delivered is a function of the cube of the diameter of the fan wheel is because the width of the fan wheel is generally made in a certain proportion to the other dimensions, and that it can be treated in that way, and then it may be reduced to that form; but I cannot find anything in this theory that would permit that assumption. It seems to me it is a gratuitous assumption which his theory does not bear out.

On page 201 he gets at the co-efficient to be used in equation 14. Equation 14 is to be considered as in some respect an empirical formula, at least a great part of it. On page 201 he gives the value for that co-efficient as 0.4. I think that is correct, because it agrees very closely with a large number of tests. I think his statements on page 202 with regard to the effect of back lash on a fan are perfectly true, and I think are of a good deal of value. The applications to practical cases I will not discuss.

The Chairman: Is there any other discussion on this paper?

Prof. J. H. Kinealy: Mr. Chairman, I want to say as a preface to my remarks, that I think this is an exceedingly valuable paper. Mr. Eisert in his work, of course, is following the European, the French and the German authorities. He follows very closely throughout both the German and the French, and the same kind of formulæ—I do not remember the co-efficients—are used not only by Murgue, whom he noticed, but also by Von Bauer and Sers—Von Bauer, the German, and Sers, the Frenchman.

The head H, of which Prof. Carpenter speaks, given in equation 1, does not mean the manometric head. The head that you would measure and obtain if you put a U tube upon the fan would be just twice what is given in equation 1. That means, however, the head which may be used either to overcome friction or to give velocity to the air, and therefore it is written in this way. I think that is the explanation for the difference between the equation and what. Prof. Carpenter has found. Now, further as to the resistance, on page 199, Mr. Eisert says, "But judging by the nature of the offered passage to the flow of the air through the heater, it can be safely assumed that the resistance increases with the square of the velocity of the passing air." If now we interpret the word "resistance" to mean co-efficient of friction, Mr. Eisert is wrong. If, however, we mean it, as we would ordinarily take the word resistance, Mr. Eisert is right. We know that the resistance offered to the passage of a fluid, liquid or gaseous, through pipes, is equal to a certain co-efficient multiplied by the square of the velocity. Now, this co-efficient is the co-efficient

of friction. But I take it that is not what Mr. Eisert means by resistance. The equation 14, that q is equal to a constant times the cube of the diameter, comes because the European engineers, at least those with whose works I am familiar, determine the capacity of a fan, not from the outlet but from the inlet, and the diameter of the inlet is always a certain fractional part of the diameter of the wheel, and the velocity of the air entering this inlet is taken very nearly equal to the velocity of the base of the blades, and that is equal to the number of revolutions per minute or per second depending upon what the velocity is, times this diameter at the root of the blade which is the same fractional part of the whole diameter of the fan that the diameter of the opening is. Hence, if you multiply the area of your opening, which varies as the square of this diameter, by the velocity you would get the cube. It is for that reason that Mr. Eisert inserts the word "single" on page 201. He says "For single inlet fans." Now for a double inlet fan e is not quite 82. If the fan is made too large then the co-efficient e will reduce and be less than it ought to be. I make these remarks in order that I may explain what my interpretation of the paper is. I consider it a valuable paper. There are, of course, mistakes in the way of typographical errors, and it seems to me that equation 16, before it is reduced, or 15, really, is the kind of an equation that we must use for fans, for the simple reason that it takes in everything involved. After you have the fan and one of these quantities is fixed, then you may eliminate that quantity or substitute for it rather a constant quantity and you get a simpler equation.

Prof. R. C. Carpenter: I am glad Prof. Kinealy has made these remarks, because he has thrown light on some points which I had not myself noticed, and especially in regard to the use of the word "head," which I have no doubt was used as he states, and which would overcome the objection which I made. In regard to the resistance the same thing would follow. The explanation he has given with regard to the cube of the diameter is one which I think should have been inserted by Mr. Eisert. The reason for making my remarks was the fact that it was not inserted.

## LXII.

# INVESTIGATIONS OF A BLOWING FAN.

BY R. C. CARPENTER.

(Member of the Society.)

(Presented at the Annual Meeting, January, 1899, revised and ordered reprinted for discussion at the Semi-Annual Meeting.)

The following paper gives a résumé of a series of experiments which have been conducted under the direction of the author during the past three years for the purpose of determining the general laws applying to centrifugal blowers of the class represented by the experimental fan.

The fan in question was constructed by E. P. Haines and S. G. Hobert in 1896, and the first investigations were made during that year by those gentlemen. Subsequent investigations were made with the same fan by H. J. Parker and P. S. Wilcox in 1897, and the writer is indebted to those experimenters for much of the material which is included in the paper.

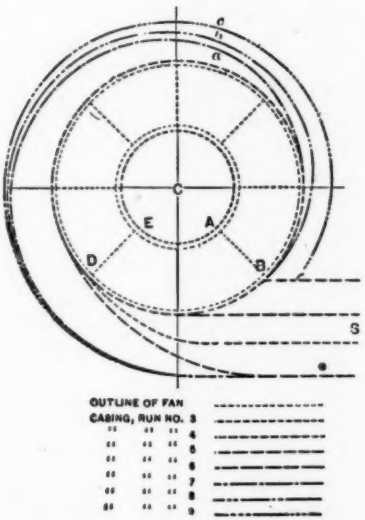
The experimental fan which was constructed for this purpose consisted of a horizontal shaft to which were fastened eight blades made of No. 16 sheet iron, each of which was 12 inches by 18 inches, and bolted to its arm to facilitate its removal or change of form. The hub of the fan was of cast iron, having a central disc to which the arms, made of $\frac{1}{8}$ angle iron, were bolted, and was held in position on the shaft by set screws, so as to be readily removable. The fan as constructed was mounted upon the overhanging end of a horizontal shaft, was 4 feet in external diameter and 18 inches in width. The casing for the sides of the fan was constructed of matched flooring 8x8 feet in size, and one side of this was braced firmly in position, while the other was arranged so that it could be moved as desired. The periphery or scroll of the case was made of a strip of sheet iron $18\frac{1}{2}$ inches in width, and arranged so that it could be fastened in any desired position to the sides of the casing with reference to the fan wheel, by means of screws and braces. A discharge passage was built, which, like the casing, had two sides adjustable

so that the area of cross section of the discharge could be varied as desired.

The fan as constructed could be adjusted in many particulars, thus presenting better opportunities for studying the laws relating to the motion of air than any of the commercial forms.

The pressure was obtained in various positions in the casing by inserting a glass tube connected by a rubber tube to a U-shaped manometer, the pressure being determined by the variation in water level in the two sides of the manometer. A number of holes were bored in the casing for this purpose.

In the first series of tests made by Haines & Hobert the fan was




driven by a separate engine, the power being determined by measuring indicator diagrams and correcting these results by the power required to overcome the friction of the engine. In the test made by Parker & Wilcox power was obtained from the main line shaft of the building, and was measured before being supplied to the fan by a transmission dynamometer; in this case no connection was necessary.

The experiments conducted by Haines & Hobert were principally devoted to determining the effect of the casing, and the variation of pressures produced in different parts of the casing. A diagram of the fan and of the various positions are shown in Fig. III, in which

figure C is the center of the fan wheel, the dotted line passing through DB is the periphery of the fan wheel; the heavier dotted line just outside shows the position of the casing, 4. In runs 4, 5 and 6 the discharge passage was varied as shown in these runs; the position of the casing in runs 7, 8 and 9 is shown respectively by the lines marked a, b and c.

The power required to run the fan under various conditions is

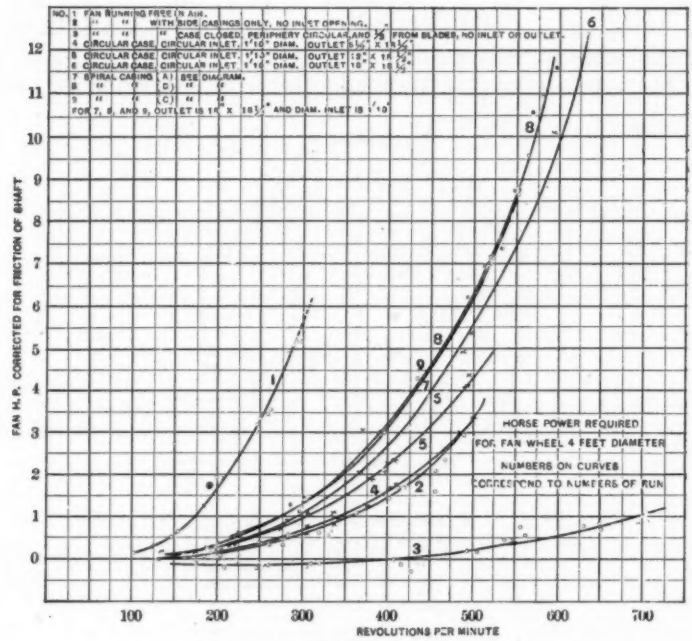

NO. 1 FAN RUNNING FREE IN AIR.
2 " " " WITH SIDE CASINGS ONLY, NO INLET OPENING.
3 " " " CASE CLOSED, PERIPHERY CIRCULAR, AND 1/8" FROM BLADES, NO INLET OR OUTLET.
4 CIRCULAR CASE, CIRCULAR INLET, 1'-10" DIAM. OUTLET 8 1/2" X 13 1/2"
5 CIRCULAR CASE, CIRCULAR INLET, 1'-10" DIAM. OUTLET 18" X 18 1/2"
6 CIRCULAR CASE, CIRCULAR INLET 1'-10" DIAM. OUTLET 18" X 18 1/2"
7 SPIRAL CASING (A) SEE DIAGRAM.
8 " " (B) " "
9 " " (C) " "
FOR 7, 8, AND 9, OUTLET IS 18" X 18 1/2" AND DIAM. INLET IS 1'-10"
FAN H.P. CORRECTED FOR FRICTION OF SHAFT
REVOLUTIONS PER MINUTE
HORSE POWER REQUIRED FOR FAN WHEEL 4 FEET DIAMETER
NUMBERS ON CURVES CORRESPOND TO NUMBERS OF RUN

PLATE 1.

shown in Plate 1, the curves being numbered to correspond with the number of run, the conditions also being given on the diagram; the quantity of air delivered for the various runs is shown on Plate 2, corresponding to the horse-power supplied the fan; the quantity of air delivered in proportion to the speed on Plate 3. The pressure in inches of water for different velocities and for different positions of manometers with radial blades is shown in Plate 4.

The various runs referred to were made under the following conditions: Run 1 was made with the fan revolving in free air with no side casing or scroll; the power for this condition was found to vary

with the cube of the number of revolutions; the horse power was equal in any given case to the cube of the number of revolutions per minute multiplied by 2.62 and divided by 10,000,000. The direction of air currents was studied by the use of dust, smoke, and light threads of cotton, from which it was noticed that with the fan running under such conditions the currents of air instead of entering principally from the center, were in fact drawn in most strongly at the sides and near the

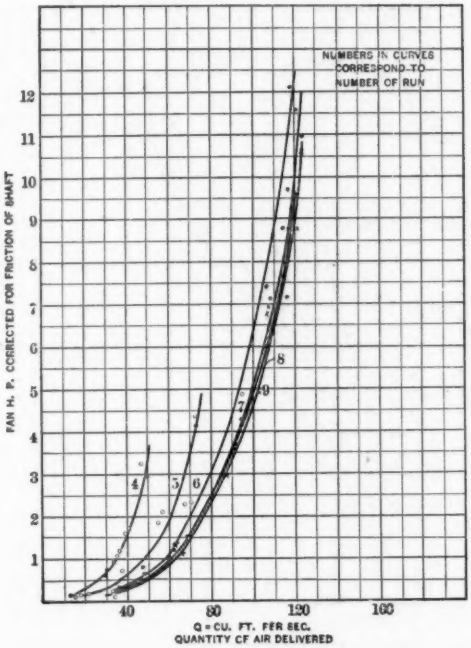



PLATE 2.

outer extremity of the blades, and even at the outer corners; the air was expelled most strongly at the middle of the outer edge, and with only a light force along the remainder of this edge. The current of air was found to leave the fan approximately at an angle of 30 degrees, with the tangent to the periphery of the wheel.

The second run was made with the sides in position, but with no inlet passage and with no scroll; manometer readings were taken in various positions to ascertain the pressure of the air at various distances from the center in the fan. The results of these tests are

shown on the various plates by the curve marked 2, from which it will be particularly noticed that a small amount of air was delivered and little power required.

The third run: In this case the peripheral casing was put in place and was adjusted circularly about the fan, allowing but one-half inch of space between the tip of the fan blade and the casing so as to form a tight cylindrical box without inlet or outlet. The results

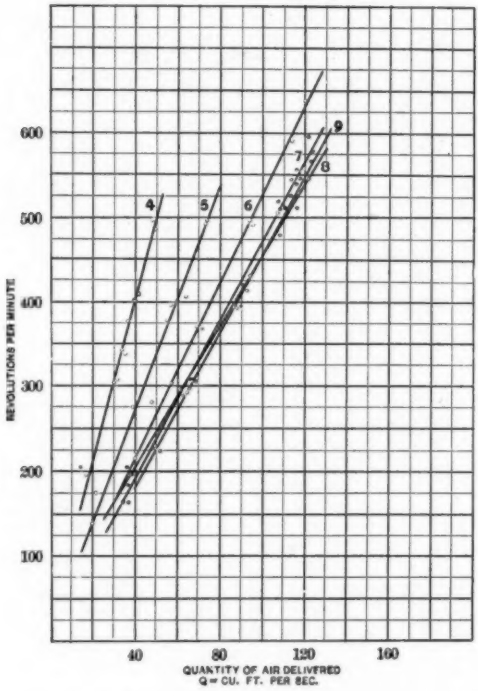



PLATE 3.

of this run are shown in curve marked 3 on the various plates mentioned, from which it will be noted that the power required was negligible below 500 revolutions per minute, and less than could be measured accurately by the instruments employed. In connection with this run it was noted that the sheet iron casing became quite warm to the hand in a few minutes, thus indicating a transformation of dynamic energy into heat energy of considerable amount. In this run

the work of the fan was utilized simply in moving the particles of air within the space occupied by the fan, and doubtless these particles were projected with considerable force against the peripheral casing.

The fourth differs from run 3 by having the peripheral casing, see Fig. III, open at the bottom, leaving an exit passage 8 feet long and 6x8½ inches in cross section. The velocity of air was measured by a Pitot tube taken at a distance of 1½ inches from the further end. The quantity of air delivered was found to vary directly with the rotative speed, as shown on Plate 3, No. 4.

Runs numbers 5 and 6 differed only from run 4 in having

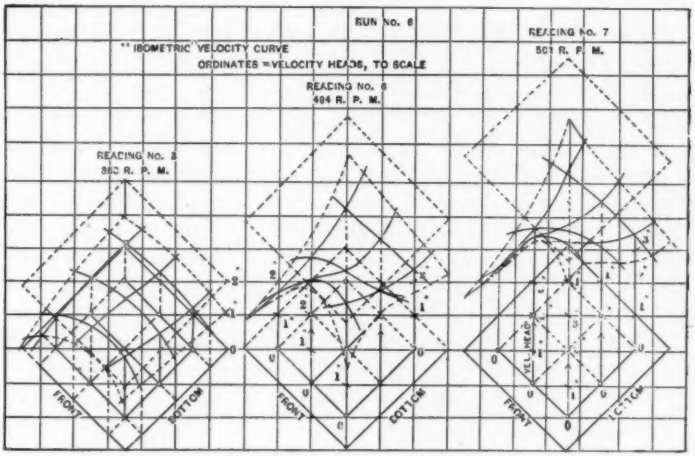



PLATE 4.

the exit passages enlarged to 12x18½ inches and to 18x18½ inches, respectively, thus providing a more ready discharge of the air. The advantage of thus enlarging the passage is shown by comparing lines numbers 5 and 6 with lines numbered 4.

Runs 7, 8 and 9 were undertaken to study the best form of case. In each of these the exit passage was 18x18½ inches in cross section, as in run 6. The scroll or spiral part of the periphery of the casing was in each of these cases a regular involute of a circle, and was described by unwinding a cord with pencil attached from small circular blocks placed in the line of the shaft. In run No. 7 the periphery of the casing was circular from the point of attachment of the upper side of the delivery box for about 45 de-

grees, and is shown by line "*a*" in Fig. 3; it ended directly underneath the center of the fan. The casing as arranged for run 18 is shown by a line marked "*b*," in Fig. III, the spiral beginning at the upper side of the delivery box, at same point as in run 7, and at a distance of ½ inch from fan wheel. The spiral for run 9 is shown by "*c*" in Fig. III, which begins at a point 6 inches back horizontally from the other spirals, but terminates at the same point. Each of these three runs showed an increase in speed of the fan per horse power applied at the engine, and also an increase in quantity of air delivered per revolution and per unit of power, and consequently an increase in efficiency for each of the runs as compared with number 6. The results obtained from these various runs is shown by the numbered lines which correspond to the number of run on plates, 1, 2 and 3. From runs 1, 8 and 9 it is seen that an increase in size of the spiral casing which increases the clearance between the fan wheel and the surrounding casing is followed by an increase of air delivered per horse power. Beyond a certain point a change in the casing would appear to make but little difference in the result, and it is probable that a position might be reached where further increase in distance would be harmful instead of beneficial, although such a position was not reached in the experiments quoted. It will be noted, however, that the difference in efficiencies between runs 8 and 9 is much less than between runs 6 and 7, which would indicate that the improvement to be obtained by increasing the diameter of the peripheral casing further would be exceedingly small. In run 9 the fan ran much more quietly at high speeds than in the other runs, which was probably due to the fact that the point at the inner end of the spiral was much further from the tips of the rotating blades. Plate 4 represents the variation in velocity in different portions of the cross section of the discharge at a point nearly 8 feet from the fan by a system of isometric projections in which the vertical distances correspond to velocity heads, and angular distances to distances measured in a vertical plane on the bottom and front of the delivery box. This is principally of importance in showing great variation in velocity in different portions of the cross section of the delivery box. In this particular case the velocity seems to have been highest near the front side, and at about one-third the height between bottom and top. Plate 5 shows the variation in pressure in inches of water when the fan with radial blades is moving at different speeds, and when the casing is closed so as to correspond to conditions in run 3.

The first investigation, the data of which have been briefly de-

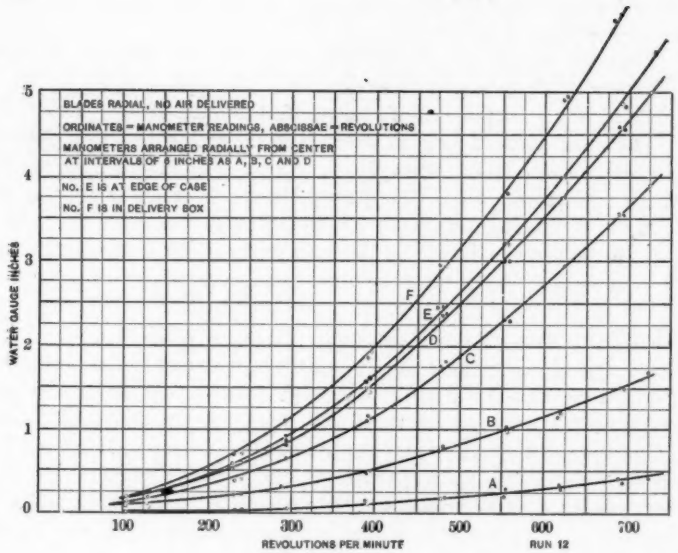



PLATE 5.

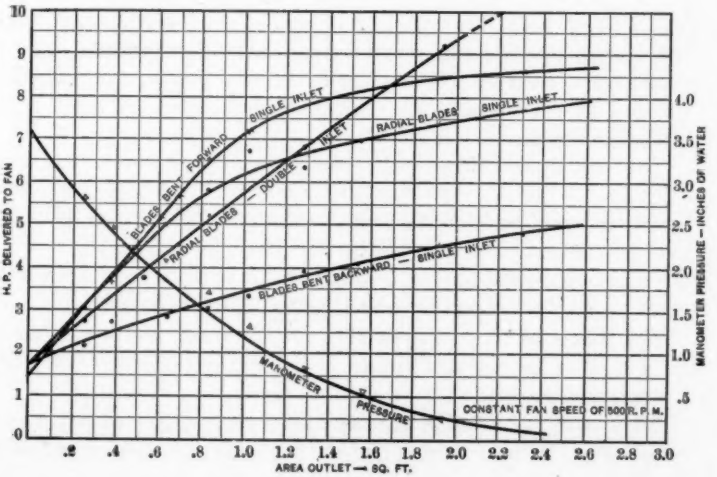

H.P. DELIVERED TO FAN
MANOMETER PRESSURE — INCHES OF WATER
AREA OUTLET — SQ. FT.
BLADES BENT FORWARD — SINGLE INLET
RADIAL BLADES — SINGLE INLET
RADIAL BLADES — DOUBLE INLET
BLADES BENT BACKWARD — SINGLE INLET
MANOMETER PRESSURE
CONSTANT FAN SPEED OF 500 R. P. M.

PLATE 6.

scribed, established the following propositions which were advanced some years ago by Murgue:

First, the volume of air delivered varies with the speed of rotation.

Second, difference of pressure varies as the square of the speed.

Third, the power required varies with the cube of the speed.

The most efficient form of the peripheral casing tested in the experiments was a spiral which began at a point 6½ inches from the tip of the blade at the top of the delivery box, and ended in a point directly under the center of the fan, being tangential with the underside of the delivery box. In the later experiments made by Parker & Wilcox the form of the peripheral casing was left in the condition found to give best results in the previous tests. The object of the later investigation was to determine the most efficient form of fan blade, and also the effect due to variation in size of outlet and inlet. For the purpose of testing fans with different-shaped blades the radial blades were removed and bent blades substituted which were radial for a distance of 7 inches, then curved in an easy bend in a direction approximating tangential at the outer extremities. The bent blades were arranged so that they could be operated with the curved end run in a backward or forward direction. The area of the plane blades in the direction of the radius was 1.5 square feet; the projected area of the curved blades on a radial plane was 1.37 square feet. As compared with the radial blades there was a loss in quantity of air delivered for a given rotative speed of nearly 25 per cent when the blades were bent backward, and but little loss when the blades were bent forward. As normally constructed, there was but one inlet to the fan, which was 22 inches in diameter. For a portion of the experiments a second inlet of the same size was constructed on the opposite side, so that experiments were made with the radial blades with two inlets.

The top of the delivery tube was constructed in two pieces, and hinged at a point 3 feet from the outer end; this hinged portion could be raised or lowered, thus changing the area of the delivery tube as required. The form of delivery tube was in all cases excepting one convergent, and of the same width as the fan; in one run a partition with a 22-inch circular opening was substituted.

The results of these various tests are shown on plates numbered from 6 to 14 by curved lines, each of which represents a different condition of the fan.

Plate 6 shows relation between horse-power delivered to fan and outlet area. It is noticeable that the blades bent backward take the smallest amount of power for a given outlet, the radial blades an in-

termediate amount, and the blades bent forward the greatest amount. The power required for the radial type of blades for very small openings was decreased, but for larger openings was increased by doubling the inlet opening, which effect is accounted for by noting that the quantity of air delivered is greatly increased for the larger openings, as shown on Plate 7. A curve showing the pressure in the delivery box in inches of water for the fan with the blades bent backward is drawn on each plate, and gives an opportunity of noting the back pressure against which the fan in that condition was working.

Plate 7 shows the relation between the quantity of air delivered in cubic feet per second and the area of outlet opening for a constant

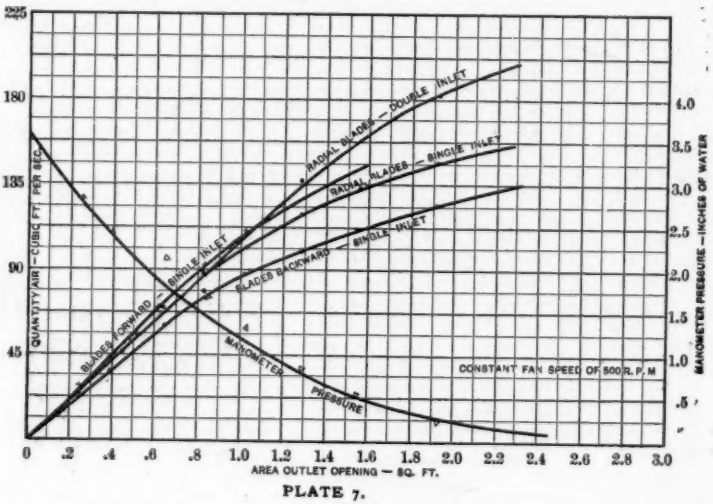



PLATE 7.

speed of 500 revolutions per minute. This plate shows that with a single inlet opening the greatest quantity of air for a given outlet area was obtained with the fan which had the blades bent forward, the amount delivered by the radial blade being intermediate, that by the blades bent backward the least. The effect of doubling inlet area was to increase the quantity of air delivered by the radial fan very materially for the larger openings.

Plate 8 shows the variation in the quantity of air delivered per horse power in cubic feet per second due to changing area of the outlet, and consequently the back pressure. In this case it is noticed that the best results are obtained from the fan with blades

bent backward. By combining the results of the plates 6, 7 and 8 it will be noted that the rounding off of the tips of the blades and bending them backward decreases the amount of air delivered, and also the power required to drive the fan, as compared with the other conditions, but it is shown on Plate 8 that the power required to drive the fan is reduced more than the delivery of air, consequently the air delivered per horse power is the greatest, or in other words, the efficiency of this type of fan is the greatest of the types compared under the same condition of inlet; but it is to be regretted that no test of the fan in this condition was made with the double inlet. Comparing the effect of doubling the area of the inlet, for the fan with radial blades, it will be noted that for a small area of outlet or

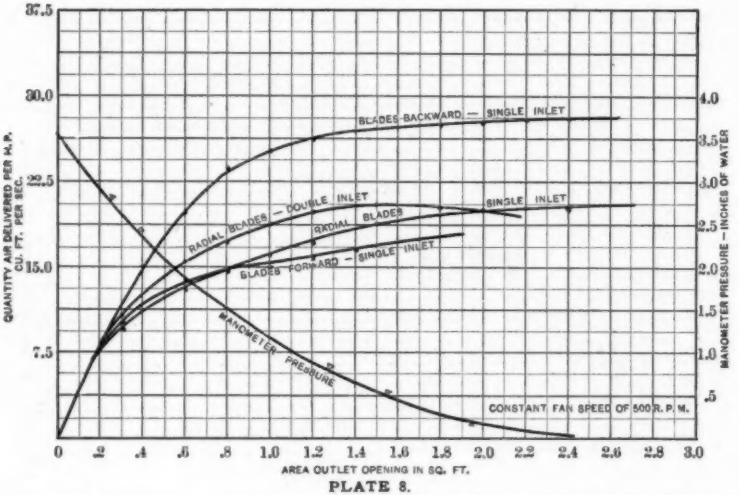



PLATE 8.

for back pressures much exceeding one inch of water, there is no special change in the results; but for large area openings, or when the pressure is less than about one inch of water, much more air is delivered; much more power is required by the fan with the double inlet, however, as shown on Plate 8. This fan is fully as efficient as the fan with the single inlet for openings somewhat greater than the area of the fan blade, or when the back pressure is reduced to about $\frac{1}{2}$ inch or less. It should be noted that numerical references to back pressures or areas of outlet apply only when the speed of fan is as given.

Plate 9 shows the relation between horse power delivered to fan and the quantity of air delivered in cubic feet per second; the speed

was constant at 500 revolutions per minute; the discharge opening and back pressure were varied. As previously mentioned, it will be

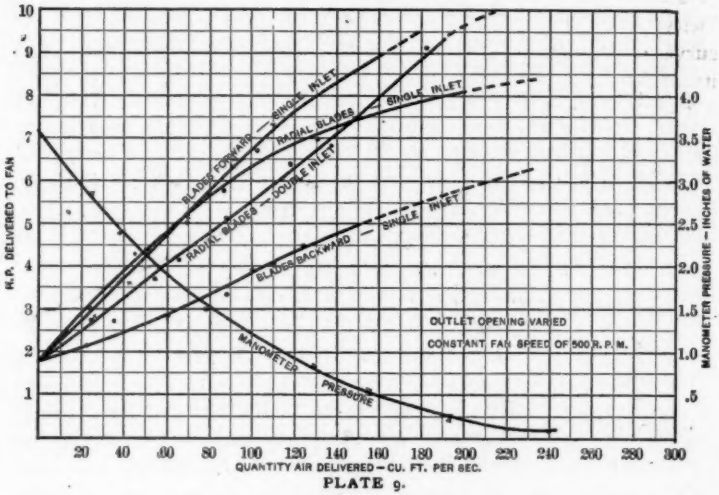

H.P. DELIVERED TO FAN
MANOMETER PRESSURE — INCHES OF WATER
QUANTITY AIR DELIVERED — CU. FT. PER SEC.
BLADES FORWARD — SINGLE INLET
RADIAL BLADES
SINGLE INLET
RADIAL BLADES — DOUBLE INLET
BLADES BACKWARD — SINGLE INLET
MANOMETER PRESSURE
OUTLET OPENING VARIED
CONSTANT FAN SPEED OF 500 R.P.M.

PLATE 9.

noted that the fan with the blades bent backward shows the least horse power for the greatest quantity of air delivered; the fan with

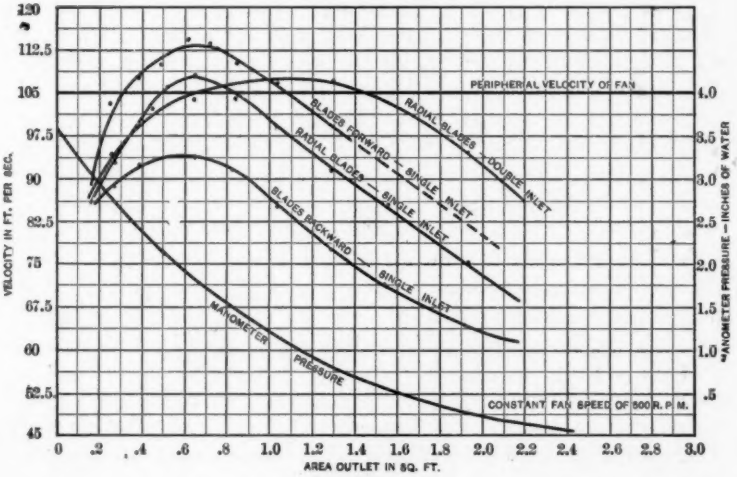

VELOCITY IN FT. PER SEC.
MANOMETER PRESSURE — INCHES OF WATER
AREA OUTLET IN SQ. FT.
PERIPHERIAL VELOCITY OF FAN
RADIAL BLADES — DOUBLE INLET
BLADES FORWARD — SINGLE INLET
RADIAL BLADES — SINGLE INLET
BLADES BACKWARD — SINGLE INLET
MANOMETER PRESSURE
CONSTANT FAN SPEED OF 500 R.P.M.

PLATE 10.

radial blades is intermediate; the fan with blades bent backward requires the most power for a given delivery.

Plate 10 shows the relation between the velocity of air delivered in feet per second and the area of outlet in square feet and the back pressure of the fan with blades bent backward. The peripheral velocity of the fan is shown on this drawing by a straight line. The curves on this plate show an interesting relation between the velocity of delivery, the back pressure and the area of outlet. It will be noted that for the two conditions of the radial blades and blades bent forward, the velocity of the discharge exceeds the peripheral velocity of the fan when the back pressure corresponds to about 1.6 inches for the case considered. For a higher or a lower back pressure the velocity becomes less, which action is doubtless explained by the fact that at a certain point the energy stored in the air is partly utilized in producing velocity; for different peripheral speeds this condition would occur at different back pressures, but the case is interesting, since it shows that under some conditions the velocity of the discharged air may exceed the peripheral velocity of the fan.

By comparing Plates 8, 9 and 10, we notice that the type of blade which has the lowest velocity gives the best result as to the quantity of air per horse power, from which it would appear that the most effective fan is the one which delivers the air at the lowest velocity, and in this respect agreeing with Murgue,* who says that "the most efficient fan is the one which receives the air without shock, and delivers it without speed." With the type of blade bent backward at the tips, the maximum velocity lacks 11 feet per second of reaching the peripheral velocity of the fan; the other three types exceed the fan velocity at the maximum point, as already mentioned. It is probable that the reason why the blades bent backward do not give so high a velocity is due to the slipping of the air over the tips of the blades. This plate also shows an interesting fact in relation to the action of the double inlet; we note that in this case the velocity does not reach its maximum until a larger outlet area is reached, that is, by increasing the inlet opening we enable the fan at a given opening, except a very small one, to keep up the quantity of air delivered without bringing down the velocity, or in other words, without lowering the pressure against which the fan works. This means that with a larger opening the doubling of the inlet area acts to increase the quantity of air delivered; but to do this for any given opening requires an increase in power and in the velocity of the fan. The general effect of enlarging the inlet tends to raise the velocity and back pressure for a given outlet, which, if carried beyond certain limits, may act against the effectiveness of the fan by sacrificing

*Dan el Murgue, Treatise on Fans, 1872.

the quantity of air per horse power. It is quite probable that the loss due to conditions which produce high velocity and high back

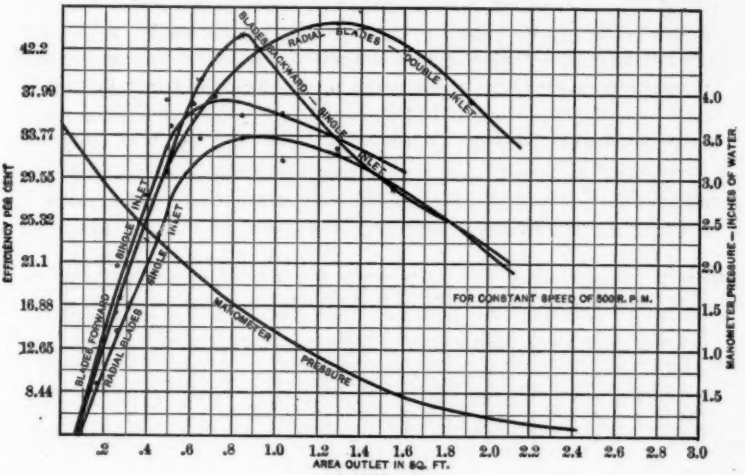



PLATE 11.

pressure are largely caused by friction, which increases very rapidly with increase in velocity of the air.

Plate 11 illustrates the relation between efficiency of the fan, the

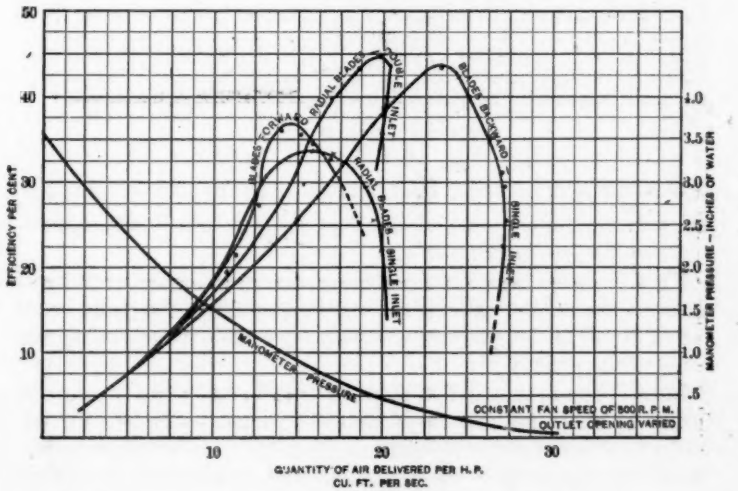



PLATE 12.

area of outlet in square feet and the pressure produced by the radial type of fan. It will be noted from these curves that each type of fan has a condition of maximum efficiency with constant speed which occurs under the condition of the test with the fan with blades bent forward when the back pressure is about 1.7 inches of water, for the fan with the radial blades when the pressure is about 1.5 inches of water, and for the fan with blades backward when the pressure is about 1.4 inches of water. It is also noted that the fans with the blades bent backward have a maximum efficiency of about 43.5 per cent; the fan with the blades bent forward has a maximum efficiency of 37 per cent, and with the radial blades a maximum efficiency of

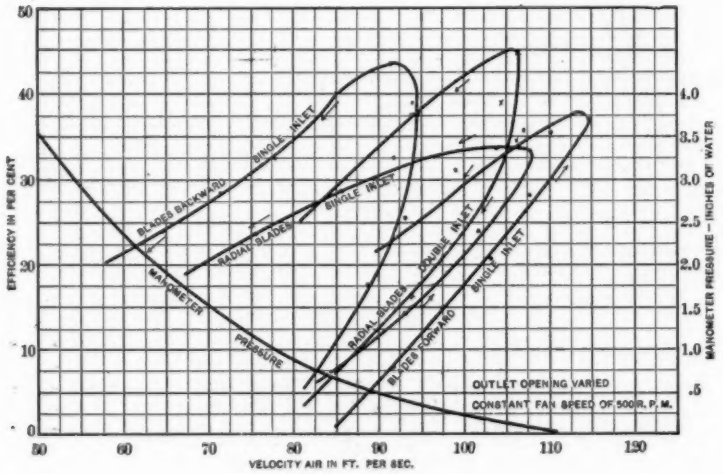



PLATE 13.

about 33.6 per cent. The fan with the radial blades, double inlet, had a maximum efficiency of about 45 per cent, which occurs, however, with a low pressure of air.

Plate 12 shows the relation between efficiency and the quantity of air per horse power, which is about the maximum at the point where the efficiency is the greatest, and with the double inlet opening this seems to be exactly true.

Plate 13 shows the relation between areas of outlet and pressure in inches of water for two cases, those of radial blades and for the blades bent backward in different position in the delivery box. The curve corresponding to the condition of the blades bent backward has been drawn on the various plates from 6 to 14.

Plate 14 shows relation between pressure in delivery box, expressed in inches of water, and the area of outlet in square feet for the various conditions, and when the fan is working at a constant speed of 500 revolutions per minute. In general, it is noticed that the fan with blades bent forward gives the highest pressure, and the fan with blades bent backward gives lowest pressure; but for openings of the delivery tube much in excess of area of the blade, the fan with the double inlet shows the greatest pressures. It will be noticed in all cases that the pressure is greatest when the delivery of air is least. Buckle * gave as results of his experiments the following formula for expressing the relation between the pressure produced

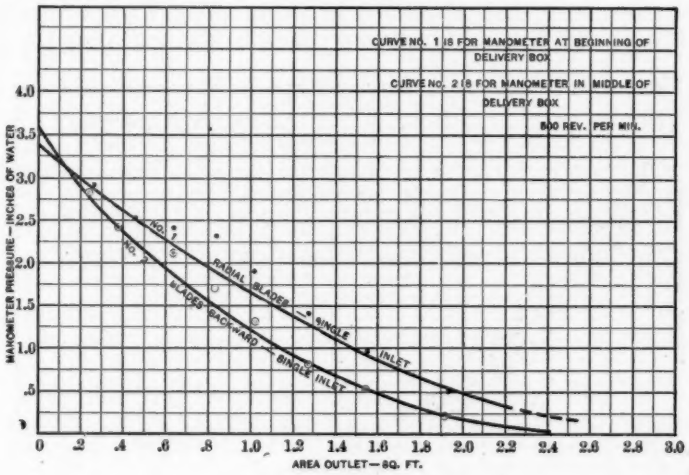



PLATE 14.

and the peripheral speed, as reduced by Kent in his "Pocket-book for Mechanical Engineers,"

$$v = 60\sqrt{p}$$

in which p is the pressure expressed in inches of water, and v is the peripheral velocity of the fan in feet per second. In the case considered the peripheral velocity of the fan was 105.5 feet per second, and the maximum pressure corresponding to this by Buckle's formula would be 3.07 inches, which is very close to the pressure shown on Plate 5 for this speed. The pressure deduced by Buckle's formula would be obtained under conditions like those in the experi-

*Paper before Institute of Mechanic l Engineers, England, 1847.

ment cited, when the area of discharge opening expressed in percentage of the area of the blade was 15 per cent when the blades were bent backward, 18 per cent when the blades were radial, and 25 per cent when the blades were bent forward. The formulas for maximum pressure which would accord with the experiment cited, and with the least possible openings for discharge of air, would be as follows:

(Haines' and Hobert's experiments; see plate 5)

$$v = 55.6 \sqrt{p}$$ Blades backward.

$$v = 52\ 7 \sqrt{p}$$ Blades radial.

$$v = 59.7 \sqrt{p}$$ Blades radial.

$$v = 49.7 \sqrt{p}$$ Blades forward.

I have found by a comparison of Buckle's formula as above with actual tests that the maximum pressure which is produced by a

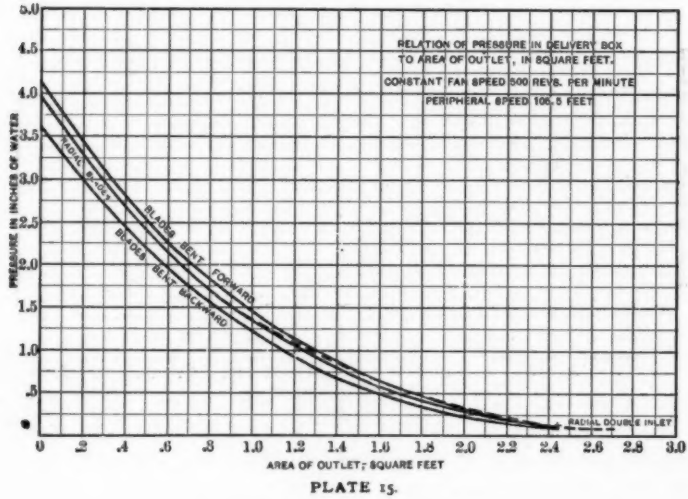



PLATE 15.

given peripheral velocity is greater than that stated by Buckle by an amount which varies in different conditions from 1 to 15 per cent. The maximum pressure which may be produced is the only one which can be considered as positively depending upon the peripheral velocity, since the actual pressure in any given case depends very largely upon the resistance to a free discharge corresponding in the case of the experiments cited to the area of outlet. The more freely the air is discharged, or in other words the less resistance, the less the pressure that will be produced by the fans. Buckle's

formula, however, is usually a safe one to employ, since the pressure given by it is less than can be realized in practice, provided the resistance to the flow of air is at a maximum. When the area of outlet gives a resistance the same as that produced by a free opening one-half the cross section of area of blade the pressures produced would be about one-half of that given by the preceding formulas, and such a condition approaches very closely that obtained in the practical use of fans. A formula which would give very closely the pressure produced under the ordinary conditions of working would, therefore, be

$$v = 80 \sqrt{p},$$

but this formula would be extremely approximate, and depend to a great extent on the resistances to the flow of air.

DISCUSSION.

Prof. Kinealy: Mr. Chairman, as a rule I am very suspicious of students' work. I have cross-checked these experiments, however, and they check up. Moreover the rule which Prof. Carpenter has used, and the area which he has found gives the best result, checks with other results. For instance, on page 216 the area of the blade is not stated exactly, but the blade is stated to be one foot by one and a half, giving an area of one and a half square feet. Now, if we will turn to plate 10, on page 227, it will be noticed that the velocity was a maximum when the area was about 1.1 square feet, a little less than the area of the blade; that is for the double inlets. Then turning to plate 11 on page 229, we find that the maximum efficiency is obtained when the area of the outlet is 1.3 square feet. The rule is that the area of the outlet shall be about the area of the blade, unless the fan is made too high to get the best results. Prof. Carpenter's final rule on page 233, $v=80 \sqrt{p}$, is the velocity in feet per second; p is the pressure in ounces. That is the rule when, as I understand it, the fan was giving the best result; that is when giving about the maximum capacity with the maximum pressure or the maximum efficiency. If we substitute for v its value in terms of number of revolutions and the diameter of the fan, you get the rule that the diameter multiplied by the number of revolutions per minute is equal to about 1,600 times the square root of p, and that is the rule you can use to check up any ordinary double inlet ventilating fan. In other words, if the pressure is one ounce and the diameter of the fan is ten feet, that fan must be run at about 160 revolutions. Then you have the proper area, an area about equal to

the area of the blade. The results check up very nicely indeed in that way, and all the way through cross check from one set of experiments or one set of curves to another. They seem to come out very nicely. So that I would like to see Prof. Carpenter say "The following paper gives a résumé of a series of experiments which have been conducted under the supervision of the author." That gives more weight. Moreover it seems to me that is really what is done. These, I take it, are really Prof. Carpenter's experiments and not experiments of boys. The boys were really the observers.

Prof. Carpenter: Yes; they were not any more than that—hardly that in some respects.

Prof. Kinealy: That gives more weight. In other words Prof. Carpenter then assumes the responsibility for these results. If he does not, unless they check with other results, they are of no value.

Prof. Carpenter: I might say in regard to Prof. Kinealy's remark that in our experimental work at the University, of course, I have entire charge of it; my whole time goes there and there is nothing goes out but what is cross checked two or three ways. These young men whose names are mentioned here, some of whom are graduate students, were men of very great skill as experimenters, and everything is cross-checked and made as accurate as possible. We sometimes make slips, and I sometimes do not see a thing when it is printed. It is usually my mistake when any is made.

## LXIII.

# THEORY OF THE CENTRIFUGAL FAN OR BLOWER.

BY R. C. CARPENTER.

(Member of the Society.)

In the following statement of the theory of fans and blowers it is assumed that the velocity of the air delivered is a function of the peripheral velocity of the tips of the fans. This, as shown by the experiments quoted, is true for a given back pressure or for a given resistance to be overcome, but varies with change in back pressure and resistance. It is, however, exactly true for constant resistances.

For the purpose of considering the theory we will use the following symbols:

Let $v$ = the velocity of the tips of the blades in feet per second, $D$ the diameter of the fan wheel, $d$ the diameter of the inlet to the fan wheel, $a$ the depth or width of the fan at the inlet, $b$ the distance between the blades at the inlet, taken in such a manner that $a\ b$ represents the area in square feet between the blades at the inlet; let $n$ = number of revolutions per second, $N$ = number of revolutions per minute, let $c$ = ratio of velocity of air to velocity of tip of fans, let $o$ = coefficient of supply at inlet, let $M$ = mass of air moved, $W$ = weight of air moved, $s$ = weight per cubic foot of air, and $Q$ = cubic feet of air. We have from general laws of geometry and mechanics

$$v = \pi Dn;\ \text{also}\ W = Qs,\quad M = \frac{W}{g}.$$

From these can be deduced the following:

Velocity of air in feet per second.

$$V = cv = \pi cnD \qquad (1)$$

Capacity of blower:

Cubic feet of air delivered per second,

$$Q = \pi coadv.$$

Substituting value of c v in (1)

$$Q = (\pi^2 co)\ (adD)n \qquad (2)$$

*Work required to run blower.*

The work done is equal to the square of the velocity as expressed in equation (1) multiplied by the mass moved. The weight is equal to the volume moved, as expressed in equation (2) multiplied by the weight per cubic foot as given in Table 8. Performing these operations as indicated, we have the following:

Useful work in
foot pounds per second =

$$\tfrac{1}{2}\, Mv^2 = \frac{W}{2g}\, v^2 = \frac{sQv^2}{2g} = \frac{(\pi \cos)}{2g}\, adv^2 \ldots\ldots\ldots\ldots (3)$$

$$\text{Horse power} = \frac{Qsv^2}{550\ (2g)}.$$

Substituting in the above the value of $v = nDn$, we have
Useful work foot pounds =

$$\frac{(\pi^4 \cos)}{2g}\, adD^3n^3 = 1.514\ (\cos)\ adD^3n^3.$$

Useful work in horse power =

$$0.0027555\ (\cos)\ adD^3n^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

From the above it will be noted that the work increases with the cube of the number of revolutions.

Certain authorities have stated as a formula for power required

$$\text{H.P.} = \frac{Qsv.}{550}$$

which is equivalent to stating that the work done is equal to the air moved multiplied by the distance traveled in feet per second, which is incorrect and sometimes very greatly in error.

The best proportions for centrifugal fans were stated by Buckle as follows: Width of vane at outlet ¼ diameter of fan, length of vane ¼ diameter of fan, diameter of inlet equal to ½ diameter of fan.

Judging from measurements of several fans the proportions in common use at the present time for ventilating purposes are about as follows:

Width of vane at outlet 0.3 diameter of fan wheel.
Width of vane at inlet 0.4 diameter of fan wheel.
Diameter of inlet ⅝ diameter of fan wheel.
Length of vane 3-16 diameter of fan wheel.

Where double inlets are used the fans should be increased in width, but I have not sufficient information to give the usual practice in this respect.

It will be noted from both these tables that both the diameter of the inlet and width of vane can be considered functions of the diameter of the fan wheel.

PRACTICAL RULE FOR CAPACITY.

By referring to formula (2) it is noted that the capacity is equal to the product of three constants multiplied by width of wheel, diameter of inlet, and by diameter of fan wheel into the number of revolutions. Since, in accordance with common practice, the last three proportions are varied together, we shall have as a practical rule for determining the capacity of fans with proportions similar to above, the following:

RULE.—*The capacity of fans, expressed in cubic feet of air delivered per minute, is equal to the cube of the diameter of the fan-wheel in feet multiplied by the number of revolutions, multiplied by a coefficient having the following approximate value:*

For fan with single inlet delivering air without pressure, 0.6; delivering air with pressure of one inch, 0.5; delivering air with pressure of one ounce, 0.4. For fans with double inlets the coefficient should be increased about 50 per cent. For practical purposes of ventilation the capacity of a fan in cubic feet per revolution would equal 0.4 the cube of the diameter in feet.

The above is obtained by substituting the following values for the coefficients in formulas (2) and (4).

$\pi = 9.94 = 10$ nearly.

$a = \frac{1}{2} D$ or less.

$d = \frac{1}{2} D$, or greater, so that $a\,d = \frac{1}{2} D^2$.

$o = 0.5$.

$c = 0.4$.

PRACTICAL RULE FOR POWER.—By substituting in a similar manner, a practical rule for power can be obtained as follows:

RULE.—*The delivered horse power required for a given fan or blower is equal to the fifth power of the diameter in feet, multiplied by the cube of the number of revolutions per second, divided by one million, and multiplied by one of the following coefficients: For free delivery 30, for delivery against one ounce of pressure 20, for delivery against two ounces of pressure 10.*

TESTS TO VERIFY RULES.—Experiments with a fan four feet in diameter give the following coefficients for capacity and horse power:

| Pressure above atmosphere per square inch. | | Coefficient for capacity. | Coefficient for horse power. |
|---|---|---|---|
| Inches of water. | Ounces. | (a) | (b) |
| 0 | 0 | 0.41 | 0.22 |
| 1 | 0.59 | 0.32 | 0.15 |
| 1.72 | 1.0 | 0.19 | 0.12 |
| 2 | 1.18 | 0.17 | 0.09 |
| 3.74 | 2.0 | 0.05 | 0.05 |

In the test of three fan wheels built with inlet opening on one side equal in diameter to $\frac{1}{2}$ fan wheel, the following results were obtained:

| Pressure above atmosphere per square inch. | | Coefficient for capacity. | Coefficient for horse power. |
|---|---|---|---|
| Inches of water. | Ounces. | (a) | (b) |
| 0 | 0 | 0.5 | 30 |
| 1. | 0.59 | 0.4 | 26 |
| 1.72 | 1.0 | 0.3 | 20 |
| 2 | 1.18 | 0.27 | 18 |
| 3.74 | 2.0 | 0.1 | 10 |

Capacity per revolution = coefficient (a) $D^3$.

Horse power = coefficient (b) $D^5n^3$.

D = diameter in feet.

The following table gives results of tests of fans used in heating the veterinary building at Cornell University:

| | LARGE FAN. | SMALL FAN. |
|---|---|---|
| Diameter of wheel, inches | 84 | 44 |
| Width at center, inches | 36 | 18 |
| Diameter inlet, inches | 84 | 28 |
| Discharge opening, inches | 40x42 | 22x22 |
| Diameter engine cylinder, inches | 19 | 6 |
| Length of Stroke, inches | 8 | 8 |
| Heating surface, lineal feet, total | 4,770 | 1,980 |
| " " " " heater | 3,816 | 1,584 |
| " " " " tempering coil | 954 | 396 |
| Lineal feet per cubic foot heated | 12.7 | 28.02 |
| Cubic feet of air per minute | 21,000 | 5,150 |
| Lineal feet of pipe, per cubic foot of air | 4.5 | 3.28 |
| Pressure in ounces | 0.875 | 0.034 |
| Revolutions engine per minute | 220 | 201 |
| Indicated horse power | 8.6 | 2.5 |
| Delivered horse power, actually found | 5.5 | 1.51 |
| Steam pressure, pounds | 22 | 22 |
| Temperature outside air | 34 | 34 |
| Temperature of room | 70 | 70 |
| Temperature of warm air | 80 | 136 |
| Heat supplied per minute B. T. U. | 4,560 | 5,180 |
| Heat per lineal foot of pipe, B. T. U. per hour | 58.8 | 195.6 |
| Pounds of steam, per sq. foot of heating surface per hour | 0.17 | 0.61 |
| Cubic feet of space heated | 121,724 | 56,732 |
| Changes of air per hour | 10.1 | 5.5 |

RESULTS COMPARED WITH CAPACITY AND POWER RULES.

| | LARGE FAN. | SMALL FAN. |
|---|---|---|
| Cube of diameter in feet | 343 | 49.2 |
| Coefficient for capacity | 0.3 | 0.5 |
| Capacity by rule | 22,028 | 5,250 |
| Fifth power of diameter in feet | 16,807 | 663 |
| $D^5n^3 \div 1{,}000{,}000$ | 0.179 | 0.053 |
| Factor for horse power | 30 | 30 |
| Horse power by rule | 5.36 | 1.16 |

PRACTICAL DEDUCTIONS.

From the results of the various tests which have been made certain general deductions may be drawn, from which practical rules

adapted for proportioning of ventilating fans of usual proportions can be deduced.

PRESSURE CORRESPONDING TO VARIOUS PERIPHERAL VELOCITIES OF FAN.
ALLOWANCE MADE FOR INCREASED DENSITY OF AIR.

| PERIPHERAL VELOCITY. | | PRESSURE PRODUCED. | | PERIPHERAL VELOCITY. | | PRESSURE PRODUCED. | |
|---|---|---|---|---|---|---|---|
| Feet per Second. | Feet per Minute. | Ounces per Square Inch. | Inches of Water. | Feet per Second. | Feet per Minute. | Ounces per Square Inch. | Inches of Water. |
| 1 | 60 | 0.000156 | 0.000269 | 140 | 8,400 | 2.83 | 4.87 |
| 5 | 300 | 0.0039 | 0.0068 | 150 | 9,0 0 | 3.23 | 5.57 |
| 10 | 600 | 0.0156 | 0.0269 | 160 | 9,600 | 3.67 | 6.32 |
| 15 | 900 | 0.035 | 0.061 | 170 | 10,200 | 4.16 | 7.14 |
| 20 | 1,200 | 0.062 | 0.107 | 180 | 10,800 | 4.70 | 8.09 |
| 25 | 1,500 | 0.098 | 0.167 | 190 | 11,400 | 5.29 | 9.15 |
| 30 | 1,800 | 0.140 | 0.281 | 200 | 12,000 | 5.93 | 10.20 |
| 40 | 2,400 | 0.250 | 0.430 | 210 | 12,600 | 6.59 | 11.34 |
| 50 | 3,000 | 0.38 | 0.65 | 220 | 13,200 | 7.27 | 12.51 |
| 60 | 3,600 | 0.52 | 0.89 | 230 | 13,800 | 7.97 | 13.78 |
| 70 | 4,200 | 0.73 | 1.26 | 240 | 14,400 | 8.69 | 14.97 |
| 80 | 4,800 | 0.96 | 1.65 | 250 | 15,000 | 9.41 | 16.19 |
| 90 | 5,400 | 1.21 | 2.08 | 260 | 15,600 | 10.17 | 17.49 |
| 100 | 6,000 | 1.49 | 2.57 | 270 | 16,200 | 10.95 | 18.84 |
| 110 | 6,600 | 1.78 | 3.07 | 280 | 17,000 | 11.75 | 20.25 |
| 120 | 7,200 | 2.11 | 3.63 | 290 | 17,600 | 12.56 | 21.61 |
| 130 | 7,800 | 2.46 | 4.24 | 300 | 18,000 | 13.39 | 23.04 |

The above results are computed from the formula:

$$v = 80\sqrt{p\left(\frac{P+b}{b}\right)}, \text{ or by transposition } p = 15.3\sqrt{\frac{V^2}{6,400} + 58.62} - 117.2$$

in which p = pressure in ounces of water, V = velocity of tip of fan in feet per second; b = barometer reading expressed in ounces (234.5) corresponding to 29.92 inches of mercury.

## LXIV.

# LITERATURE RELATING TO BLOWING FANS.

BY R. C. CARPENTER.
(Member of the Society.)

The following compilation of titles of various papers which have been published from time to time in relation to blowing fans was made by S. G. Hobert and E. P. Haines, graduates of Sibley College, Cornell University, in 1896. The references are extensive, and although probably not exhaustive, will be found of sufficient value to those who are interested in the study of ventilating problems to warrant publication in a form where they will be permanently accessible.

It will be noticed that the list of literature on this subject is quite extensive, and this in turn indicates that a great amount of labor has been devoted in the past to the solution of problems relating to the construction and use of blowing fans. Attention has been called in previous writings to the fact that the information given in the various trade catalogues of blowers was often misleading, especially in reference to capacity and power, and many have erroneously supposed that this was due to the fact that the investigations relating to mechanical methods of moving air were extremely limited in extent.

It might be stated that much valuable information in relation to the blowing fan has been from time to time printed in various trade publications which are not referred to in this list, but which fill an important place when studying problems relating to moving air.

## LIST OF PAPERS RELATING TO BLOWING FANS.

FROM INSTITUTION OF MECH. ENGRS. (Birmingham).

1847, May 3, pages 3-12; paper by W. Buckle on a "Series of Experiments Relating to Fan Blasts." Experiments to obtain power required; gives tables and formulæ, deduces proper proportions for fans.

1847, October 3, supplementary paper on the above.

1859, page 52-56; Lloyd's fan, mentioned in paper and illustrated.

1859, page 251-258; "Nasmyth Ventilating Fan," paper by E.

Rogers. Experiments; tables; shows advantage of fan over furnace for mere ventilation.

1869, page 78-100; paper by Jas. S. E. Swindell. Summarizes previous papers and describes Guibal's and Waddle's fans; also discussion.

1869, paper by Wm. Cochran, of Newcastle. Illustrates and describes various types of ventilators then in use, with their efficiencies, etc.; gives tables.

1875, page 317-332; paper by W. Daniel, "Mechanical Ventilation of Houses," and interesting discussion of paper. Experiments; tables; description of methods.

Papers on Positive Blowers; 1858, page 63-147; 1869, page 79-146; 1877, page 92; 1878, page 462.

Papers on ventilation of Buildings, Collieries, etc.; 1851; 1863, page 194; 1867, page 61; 1897, a paper by W. G. Walker.

FROM INSTITUTE ENGINEERS IN SCOTLAND.

1857, Vol. 1, page 20; paper by Mr. John Downie, "Our Blowing Fans." Experiments made about 1847, compares single and double outlet, and gives tabulated data.

1857, Vol. 1, page 25; paper by W. J. Macquorn Rankine, on "A Blowing Fan." Discusses fan construction, as to blades, cases, etc., advises large cases, gives some formulæ.

1870, Vol. 14, page 71; paper and discussion by D. P. Morrison "On the Economic Advantages of Mechanical Ventilation." Shows advantages of mechanical ventilation over furnaces for mines. Tabulates experiments (between 1836-1870) on different systems of ventilation; compares cost of fans and furnaces under similar conditions.

PROCEEDINGS INSTITUTE OF C. E. (LONDON)

1870, Vol. 30, page 276; "On the Conditions and Limits Which Govern the Proportions of Rotary Fans," by Robert Briggs, Philadelphia. Experiments to determine forms of blades and spiral; tables of calculations and tests.

1877, Vol. 47, page 405; "Theory of Centrifugal Fans," abstract by D. K. Clark from paper by M. Arson. Bulletin de la Société des Ingenieurs Civils; 1876, page 728; "Discussion, Chiefly on Best Form of Blades." No conclusions.

1879, Vol. 55, page 418; "Increased Rarefaction by Combination of Centrifugal Ventilators," by J. Herrin. Revue Universelle des

Mines, 1878, Vol. 3, page 754; Operation of Guibal and Laubert Ventilators.

1879, Vol. 57, page 411; "Theory of Centrifugal Fans, Their Form and Dimensions." Abstract by D. K. Clark on paper by L. Ser in Comptes rendus de la Société des Ingenieurs Civils, August, 1878, page 629; which contains tables of observed and calculated data.

1881, Vol. 66, page 266; "Centrifugal Ventilators for Mines," by D. Murgue. Translated by Alf. Bache from Bulletin de la Société de l'Industrie Minerale. 1880, page 5; 1873, page 445; 1875, page 747; article gives Murgue's theory and also some tests. 1882, Vol. 69, page 482; "Guibal Fan at Comberedonde Colliery," from Bulletin de la Société de l'Industrie Minerale. 1881, Vol. 10, page 109; this article contains tabulated summary tables of some tests made by Murgue.

1885, Vol. 79, page 425; "An Underground Guibal Ventilator at Planitz," by B. Otto, from Zeitschrift fur das Berg-Hutten und Salien-Wesen. 1884, page 159; description of fan and situation.

1886, Vol. 85, page 476; "Volumetric Regulator for Ventilating Fans," by L. Desailly, from Bulletin de la Société de l'Industrie Minerale, 1885, page 1073; description of the apparatus.

1891, Vol. 103, page 468; "On a Capell Fan at Berg-Borbeck," by M. Kattwinkel, from Zeitschrift fur das Berg-Hutten und Salien-Wesen, 1890, page 347; description of fan, results of tests and formulæ to be used.

1893, Vol. 113, page 435; "Report of Belgian Commission on Large Mining Fans," from Revue Universelle des Mines, 1892, Vol. 20, page 133; the article gives the results of tests made by the commission.

## LXV.

# HEATING WITH STEAM AT OR BELOW ATMOSPHERIC PRESSURE.

BY J. H. KINEALY.
(Member of the Society.)

In order to circulate steam in a heating system it is necessary that the pressure in the radiators and piping of the system, before steam is turned on, shall be less than the pressure at which the steam is to be circulated. That is, if steam is to be circulated in a system at atmospheric pressure, the pressure in the system before the steam is turned on must be less than atmospheric pressure; and if steam is to be circulated at a pressure of 2½ pounds less than atmospheric pressure, or with a vacuum of five inches, the pressure in the system before the steam is turned on must be more than 2½ pounds less than atmospheric pressure, or the vacuum must be greater than five inches. Therefore, in order to circulate steam at or below atmospheric pressure, it is necessary that a greater or less vacuum shall be made in the entire system, by means of an air pump and exhauster of some kind, before steam is turned on the system. If no air accumulated in the system from the steam, and if it were possible to erect a system, all of whose connections and joints would be perfectly air tight, it would be necessary to create this vacuum only once; but as air always accumulates in the radiators, and as it is almost impossible to keep the joints and connections of a system air tight, this vacuum must be created every time the system is heated up, or about once a day. After the vacuum is created, it must be maintained; and hence the air pump or exhauster must be ready at all times to remove air from the radiators. Of course, when steam is circulated at or less than atmospheric pressure, the temperature of the steam and the radiators will be equal to or less than 212 degrees, and this means that the radiators are considerably cooler than when steam is circulated through them at five or ten pounds pressure.

The questions which naturally present themselves in regard to circulating steam at or below atmospheric pressure are:

First. Is there any saving or advantage in the lower pressure?

Second. Is there any saving or advantage in heating at a lower temperature?

Whenever the steam used for heating is the exhaust from non-condensing engines and is circulated at a pressure somewhat less than atmospheric pressure, there is no back pressure on the engines, and the heating is obtained for almost nothing. This is so evident that it is not necessary to dwell upon it. But when the steam for heating is not the exhaust steam from engines, there appears to be no advantage in having the pressure less than atmospheric pressure, unless it can be shown that the advantage comes with that lower temperature which accompanies the lower pressure.

It has been maintained by some of those firms which own and control the various systems for circulating steam for heating purposes at or below atmospheric pressure, that there is a very decided advantage and economy due to the lower temperature of the steam in the radiators, and one or two attempts have been made to explain to what this economy is due. Up to early last spring I had paid very little attention to this claim. It was brought to my attention last March by being asked to serve with Mr. Wm. H. Bryan and Mr. E. C. Parker, both of St. Louis, as a committee to make some tests to determine whether or not there was any economy in circulating steam at a temperature of 212 degrees or less.

The tests were made in a small room 11x14 feet, with a height of 12 feet, which was partitioned off from a large room on the ground floor of the Turner Building, in St. Louis. The room had one outside wall about 28 inches thick in which there was a window 5½x7 feet, and three inside walls each about 9 inches thick. By opening the doors and windows of the larger room it was possible to have about the same temperature in the larger room that there was outside, and thus to have all of the walls of the smaller or test room subjected to the same outside temperature during a test. The general arrangement of the apparatus is shown in isometric in Fig. 1: *a* represents the steam pipe through which steam was supplied from the boiler at a gauge pressure of 70 to 80 pounds; *b* is a separator through which the steam passed; and *c* is a reducing valve by means of which the pressure of the steam was reduced to about five or ten pounds; *d* is a separator through which the steam was obliged to pass immediately before entering the radiator. The radiator was an ordinary, ten loop, Perfection radiator, 38 inches high. It was rated at 40 square feet of heating surface. The condensed water left the radiator through the pipe *i* and passed into the re-

ceiver *k*, where it was caught, and from which it was drawn off from time to time and weighed; *e* and *h* are pressure gauges, and *g* is a recording gauge; *l* is a Paul exhauster, by means of which a vacuum was maintained in the air line of the system when steam was to be circulated at a pressure less than atmospheric pressure;

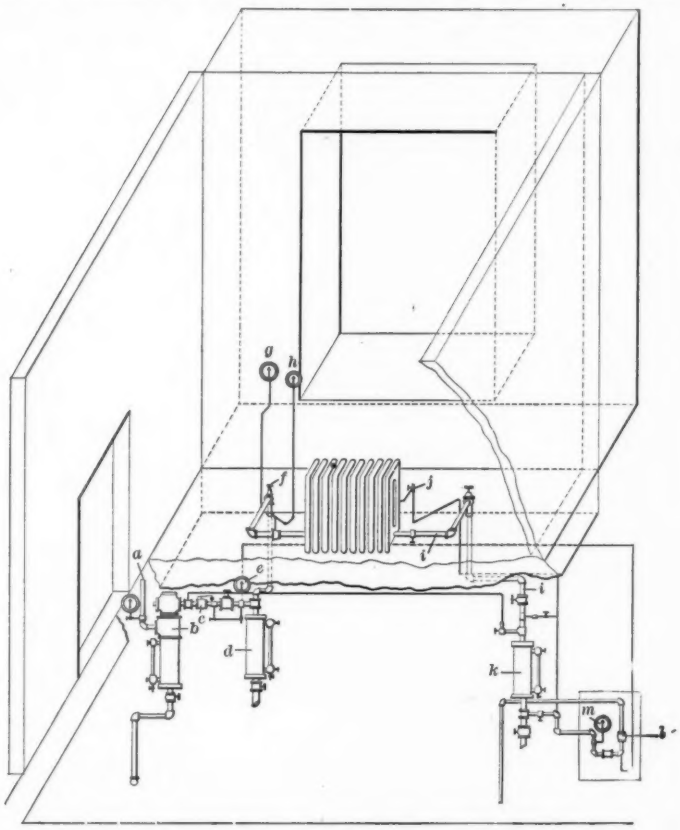



Fig. 1.

*j* is a Paul air valve, and *m* is a gauge for indicating the vacuum on the exhauster. By means of the valve *f* the steam was throttled so as to maintain any desired pressure in the radiator, readings of which were taken every fifteen minutes during the test. Two thermometers were hung in the heated room, both about five feet from the floor. The bulb of one was protected by a cylinder of paste-

board from direct radiation from the radiator; the other was exposed as thermometers usually are in heated rooms. The outside temperature was obtained by taking the average of the readings of three thermometers. One was hung north of the heated room in the open window of the large room; one was hung in the large room, west of the heated room; and one was hung in the large room, south of the heated room. The readings of the three thermometers were nearly the same. There was, of course, at times, a difference, but it was never very great. The temperature indicated by the exposed thermometer in the heated room was taken as the temperature of the room, and it was almost invariably about one-half of one degree higher than the temperature shown by the shielded thermometer.

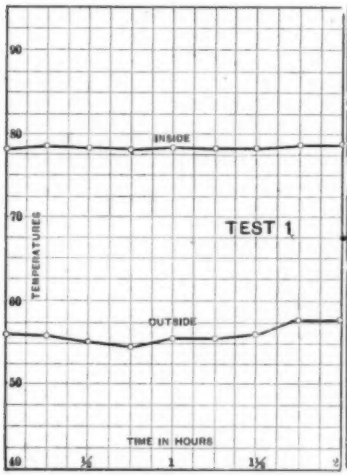



Fig. 2.

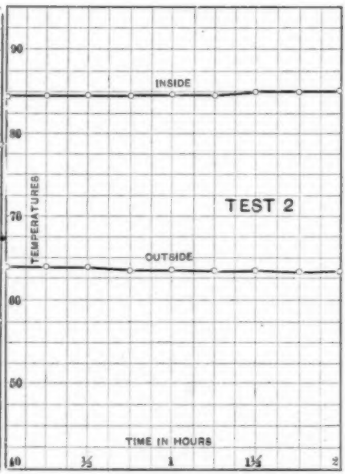



Fig. 3.

The committee were able to make only six tests, as the agent of the building informed them after the sixth test was finished that he had rented the room, and he wished the apparatus to be moved out. The results of these six tests I am allowed to present to the Society. The log for the inside and outside temperature of each test is given below, and in order to show the changes of temperature inside and outside, the temperatures have been plotted on the accompanying diagrams. Fig. 2 shows the temperatures for test 1, made with a twenty inch vacuum in the radiator; Fig. 3 shows the temperatures for test 2, made with a vacuum of ten inches in the

radiator; Fig. 4 shows the temperatures for test 3, made with zero or atmospheric pressure in the radiator; Fig 5 shows the temperatures for test 4, made with a gauge pressure of five pounds in the radiator; Fig. 6 shows the temperatures for test 5, made with a gauge pressure of ten pounds in the radiator; and Fig. 7 shows the temperatures for test 6 made with a gauge pressure of five pounds in the radiator.

Tests 4 and 5, when the pressure in the radiator was five and ten pounds respectively, were made soon after tests 1, 2 and 3, during which time the radiator had been kept entirely free of air by the Paul system. Test 6 was made after the radiator had been heated up in the ordinary manner by turning on steam at five pounds pres-

## Logs of Tests Made at St. Louis.

TEST 1.
MARCH 14, 1899.
20 inch Vacuum in Radiator.

| Time P. M. | Inside Temperature | Outside Temperature |
|---|---|---|
| 5:15 | 78 | 56.3 |
| 5:30 | 78⅛ | 56.0 |
| 5:45 | 78¼ | 55.2 |
| 6:00 | 78 | 54.8 |
| 6:15 | 78½ | 55.7 |
| 6:30 | 78 | 55.5 |
| 6:45 | 78 | 56.2 |
| 7:00 | 78⅛ | 57.8 |
| 7:15 | 78¼ | 57.7 |

TEST 2.
MARCH 15, 1899.
10 inch Vacuum in Radiator.

| Time A. M. | Inside Temperature | Outside Temperature |
|---|---|---|
| 12:00 | 84⅛ | 64 |
| 12:15 | 84⅛ | 64 |
| 12:30 | 84⅛ | 64 |
| 12:45 | 84⅛ | 63.7 |
| 1:00 | 84¾ | 63.8 |
| 1:15 | 84¾ | 63.5 |
| 1:30 | 85 | 63.5 |
| 1:45 | 85 | 63.2 |
| 2:00 | 85 | 63.3 |

TEST 3.
MARCH 15, 1899.
Atmospheric or Zero Pressure in Radiator.

| Time A. M. | Inside Temperature | Outside Temperature |
|---|---|---|
| 3:00 | 87 | 60.5 |
| 3:15 | 87 | 60.0 |
| 3:30 | 8 | 60.7 |
| 3:45 | 87 | 56.0 |
| 4:00 | 87⅛ | 55.3 |
| 4:15 | 87⅛ | 53.3 |
| 4:30 | 87¼ | 52.3 |
| 4:45 | 87 | 51.7 |
| 5:00 | 87⅛ | 50.7 |

TEST 4.
MARCH 15, 1899.
5 pounds Gauge Pressure in Radiator.

| Time A. M. | Inside Temperature | Outside Temperature |
|---|---|---|
| 6:00 | 88 | 51 |
| 6:15 | 88⅛ | 48 |
| 6:30 | 88¼ | 48 |
| 6:45 | 88⅛ | 47.5 |
| 7:00 | 88¾ | 46.3 |
| 7:15 | 88¾ | 46.7 |
| 7:30 | 88¾ | 46.0 |
| 7:45 | 88¾ | 45.7 |
| 8:00 | 88¾ | 44.3 |

TEST 5.
MARCH 15, 1899.
10 pounds Gauge Pressure in Radiator.

| Time A. M. | Inside Temperature | Outside Temperature |
|---|---|---|
| 10:00 | 89¼ | 42.8 |
| 10:15 | 89¼ | 43.7 |
| 10:30 | 89¼ | 42.5 |
| 10:45 | 89¼ | 43.0 |
| 11:00 | 89⅛ | 42 8 |
| 11:15 | 89⅛ | 44.0 |
| 11:30 | 89⅛ | 42.7 |
| 11:45 | 89⅛ | 41.5 |
| 12:00 | 89⅛ | 42.5 |

TEST 6.
MARCH 16, 1899.
5 pounds Gauge Pressure in Radiator.

| Time | Inside Temperature | Outside Temperature |
|---|---|---|
| 11:30 P.M. | 82¾ | 47.3 |
| 11:45 | 83 | 46.8 |
| 12:00 | 83 | 46.0 |
| 12:15 A.M. | 83 | 46.0 |
| 12:30 | 83 | 45.8 |
| 12:45 | 83¼ | 45.8 |
| 1:00 | 83¼ | 45.8 |
| 1:15 | 83¼ | 46.7 |
| 1:30 | 84½ (?) | 45.8 |

sure, and making the steam force the air out of the radiator through an ordinary air valve of the float type. Each test lasted two hours, and during the test there was as a rule only one occupant in the heated room. He regulated the valve on the steam supply pipe so as to maintain the proper pressure in the radiator, and also took readings of the thermometers in the room, and of the pressure gauge *h*, shown on Fig. 1. After a test was started the door between the heated room and the outside room was kept closed, and great care was taken to keep the conditions throughout the test as nearly uniform as possible. No test was taken until the temperature inside had reached a condition of equilibrium, and an inspec-

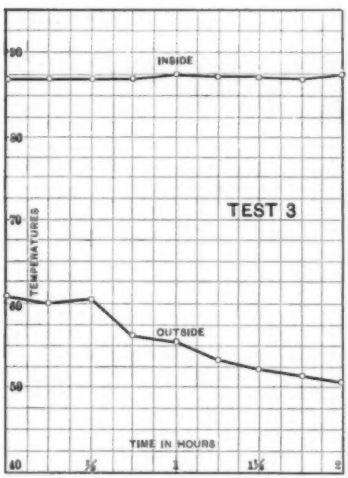



Fig. 4.

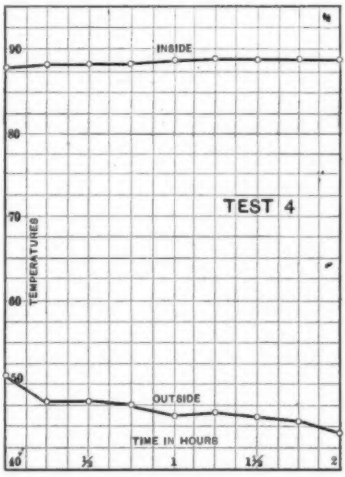



Fig 5.

tion of the diagrams, or the logs of the test, will show that there was a rise of less than a degree during any one test. The last reading of the inside temperature of test 6 shows there was a very decided change during the last fifteen minutes of the test.

As the observer thought that this rise was probably due to the way in which he had allowed the lamp to heat the thermometer while taking some other readings, this reading was discarded, and the final reading taken the same as the reading previous.

During test 1 there was some fluctuation in the outside temperature. During the first hour there was a fall of about one degree, and during the second hour a rise of about two degrees. This, how-

ever, was not a very marked fluctuation, and probably exerted very little influence upon the results of the test.

During test 2 the outside temperature was quite constant, the total change in temperature during the entire test being less than one degree.

During test 3 there was a very decided drop in the outside temperature. At the beginning of the test the temperature was a little over sixty degrees and it remained almost constant for about one-half hour; then there was a sudden drop, and at the end of the first hour the temperature had fallen about five degrees. And from then

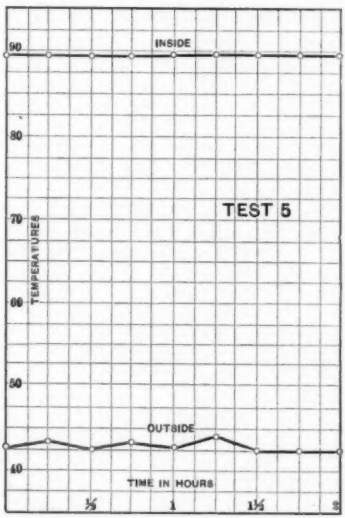



Fig. 6.

on there was a steady, almost uniform, decrease in the temperature until the end of the test. The total drop in the temperature during the test was about ten degrees. Five degrees occurred during the second half of the first hour, and five degrees during the last hour of the test. It is to be noted that in spite of this very decided drop of outside temperature, which made the difference between the outside and inside temperatures increase from about twenty-eight to about thirty-seven degrees, the inside temperature remained almost constant at eighty-seven degrees during the entire test. That is, during this test the radiator supplied heat enough to maintain a constant inside temperature in spite of a very decided drop of out-

side temperature. Of course, there was a certain cooling of the walls during this change of outside temperature, so that the radiator probably was not called upon to supply quite as much heat as it would had the walls not been warm. It is hardly probable, however, that the heat from the walls exerted any very marked influence upon the inside temperature, tending to keep it constant in the face of this decided drop in outside temperature. The drop was so great that in working up the results of the test for this paper I have taken into account *only the last hour* of this test. So far as could be judged from the water condensed each fifteen minutes of the test, the condensation was about unform for each quarter of an hour during the entire test.

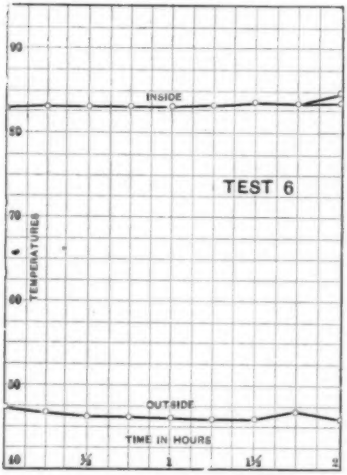



Fig. 7.

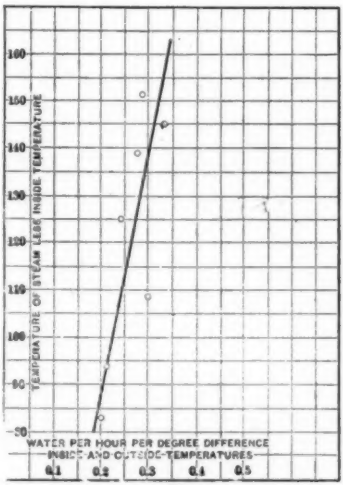



Fig. 8.

During test 4 there was a rise of the inside temperature of only about three-fourths of a degree, but a drop in the outside temperature of about seven degrees; and, therefore, in working up this test for this paper I have considered only *the last hour* of the test, during which there was a drop in the outside temperature of only about two degrees. The water condensed during the last hour was, as far as could be judged, about the same as during the first hour or one-half of what was condensed during the whole test.

During test 5 the inside temperature was exceedingly uniform, but the outside temperature was erratic, rising and falling, but never changing very much.

During test 6 the inside temperature was quite constant, assuming that the last reading was an error and was due to the thermometer being inadvertently heated in some way. The outside temperature fell about two degrees during the test.

The tests had been really undertaken with the object of determining whether or not it is more economical to heat with steam at zero pounds than with steam at five pounds, but the tests were made with steam at the higher and lower pressures shown on the logs in order to determine more accurately whether or not there was a saving, and whether or not this saving continued as the pressure

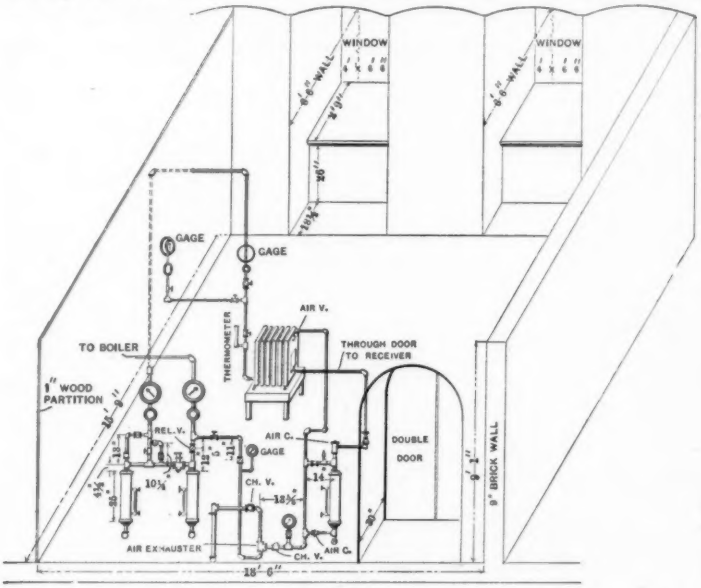



Fig. 9.

was decreased below atmospheric pressure, and also whether there was any difference between heating with steam at five and ten pounds. In other words, the boundaries of the survey were extended in order to get a broader and better view of the whole subject. I for one was working in the dark, and had no idea what kind of results would be obtained. Inasmuch as the inside and outside temperatures during the tests were not those which should be expected during a cold winter's day, it was thought best to compare the results on the common basis of the number of pounds of steam condensed per hour, per degree of difference of inside and outside

temperatures. That is, the amount of steam condensed per hour during each test was divided by the difference between the average inside temperature and average outside temperature for the test. In table 1, given below, are shown the results of the different tests, taking into account, however, only *the last hour of test 3 and of test 4*. It should be remembered that what is called the inside temperature in the table is, for each test, the average of the readings of the thermometer hung about five feet from the floor of the heated room, and exposed to the direct contact of the air in the room and the heat radiated from the radiator.

The table shows that tests 4 and 5 do not agree, and that test 2 shows a greater amount of water used per degree difference of inside

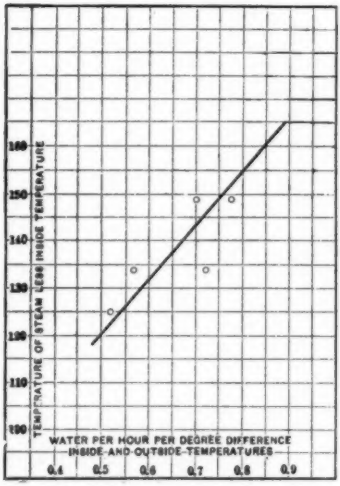



Fig. 10.

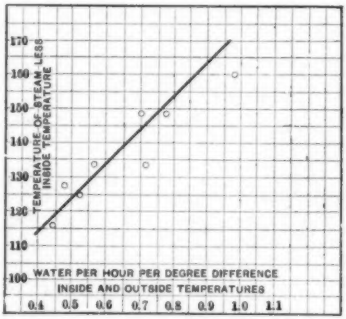



Fig. 11.

and outside temperatures per hour than either test 3, 4, or 5. On the whole, however, the tests indicate that the less is the difference between the temperature of the steam and the temperature of the air in the room, as measured about five feet from the floor, the less is the amount of steam used per hour per degree difference of inside and outside temperatures. This is very apparent if we neglect tests 2 and 6, but in order to make it more apparent there has been plotted on the diagram, shown on Fig. 8, the amounts of water used per hour per degree difference of inside and outside temperatures for the various differences between the temperature of

the steam in the radiator and the temperature of the air in the room. On this diagram the vertical scale represents the difference between the temperature of the steam and the temperature of the room, and the horizontal scale represents the number of pounds of water used per hour per degree difference of inside and outside temperatures.

The line on the diagram shows what is probably the relation, as indicated by these tests, between the amount of steam used per hour per degree difference of inside and outside temperaturs, and the difference between the temperature of the radiator and that of the air in the room.

The heat used per degree difference of inside and outside temperature is equal to the latent heat of the steam multiplied by the

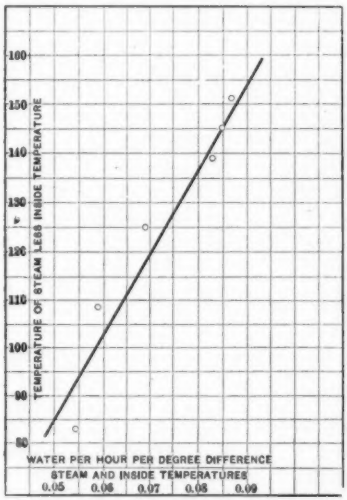



Fig. 12.

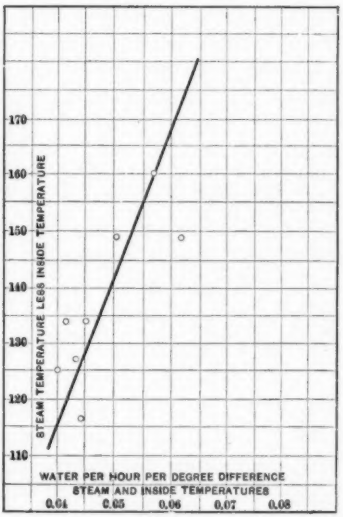



Fig. 13.

number of pounds of steam used, but the latent heat of steam varies very little for pressure between five pounds less than atmospheric pressure and five pounds gauge pressure. The latent heat at five pounds less than atmospheric pressure is about 980, and the latent heat at five pounds gauge pressure is about 955, a difference of only 25 heat units; or the latent heat at five pounds less than atmospheric pressure is only about 2.6 per cent greater than the latent heat at five pounds gauge pressure. If now a room were maintained at a temperature of 70 degrees with steam at a pressure of five pounds less than atmospheric pressure, the difference between

the steam in the radiator, 193 degrees, and the temperature of the air in the room, 70 degrees, would be 123 degrees; and according to the diagram in Fig. 8 about 0.265 pounds of steam would be used per hour per degree difference of inside and outside temperatures. If the room were kept at 70 degrees with steam at a gauge pressure of five pounds, the difference between the temperature of the steam, 228 degrees, and the temperature of the air in the room, 70 degrees, would be about 158 degrees; and according to the diagram in Fig. 8 about 0.335 pounds of steam would be used per hour per degree difference of inside and outside temperatures. That is, about 25 per cent more steam would be used at the higher pressure than at the lower pressure. This difference is so great that it cannot be accounted for by the small difference, something like $2\frac{1}{2}$ per cent, in the specific heat of the steam at the two pressures.

Through the courtesy of Mr. A. G. Paul I obtained copies of the logs of tests similar to those made at St. Louis, which were made in

TABLE 1.

| Test | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Pressure in radiator | —10 lbs | —5 lbs. | 0 | 5 lbs. | 10 lbs. | 5 lbs. |
| Length of test, hours | 2 | 2 | 1 | 1 | 2 | 2 |
| Steam temperature | 161 | 193 | 212 | 228 | 240 | 228 |
| Inside temperature | 78 3 | 84 8 | 87 3 | 88 8 | 89 4 | 83 1 |
| Outside temperature | 56 0 | 63.7 | 52 3 | 45.9 | 42 9 | 46.2 |
| Difference between steam temperature and inside temperature | 83 | 1'8 | 125 | 139 | 151 | 145 |
| Difference between inside and outside temperatures | 22.3 | 21.1 | 35.0 | 42.9 | 46 5 | 36 9 |
| Pounds of steam condensed per hour | 4 53 | 6.34 | 8.56 | 11.63 | 13 09 | 12.28 |
| Do., pe degree difference of inside and outside temperatures | 0.203 | 0.300 | 0.243 | 0.271 | 0.282 | 0.333 |

May, 1899, at Washington, D. C., under the direction of Chief Engineer G. W. Baird, of the United States Navy. The arrangement of the apparatus used in making the tests was very similar to that used in the tests at St. Louis, and is shown in isometric in Fig. 9.

In all, fourteen tests were made; with pressures in the radiators ranging from a vacuum of twenty inches to a gauge pressure of ten pounds. Of these fourteen, however, I have rejected six, as the conditions under which they were made were such that I do not think they are comparable with the others. Of the remaining eight, five I consider as strictly comparable with one another. The conditions under which they were made appear to be pretty much the same except, of course, as to the temperature of the steam in the radiator and the temperature of the room being heated. The other three of the eight tests which I have used are comparable with one another, but are not strictly comparable with the five spoken of above. The difference in the conditions under which these tests

were made is due to the manner of obtaining the outside temperature. The wood partition shown in Fig. 9 separates the room in which the tests were made from a carpenter shop, and the outside temperature was taken as the average of the readings of two thermometers, one of which was hung in an areaway outside of the heated room, and the other was hung in the carpenter shop. In the five tests which I consider comparable with one another, the temperatures as indicated by the two thermometers differ from one another only by, at the most, three or four degrees, but in the three tests which I think are not exactly comparable with these five, the temperature in the carpenter shop was about midway between the temperature in the heated room and the temperature in the areaway.

It is unnecessary to publish here in detail the logs of the tests, but in table 2 are given the results, as worked up by me, of the eight tests which I have used. I should state that I, and only I, am responsible for the results of the calculations which are given in table 2. The temperatures, inside and outside, I have obtained by taking the average of the readings of the thermometers for the different tests as given in the logs. The amount of steam condensed during each test I have also taken from the logs. The calculations, however, in which these quantities have been used have been made by me.

Of the tests shown in table 2, those of May 5, 6, 8, 19 and 20 are the ones which I consider comparable with one another. The tests of May 18, 22 and 26 are those which, while comparable with one another, are not exactly comparable with the tests of May 5, 6, 8, 19 and 20. As in the tests made in St. Louis, it is found that there are here some discrepancies in the results obtained for the same pressure of steam in the radiator. That is, the tests of May 8 and 20, both made with atmospheric pressure in the radiator, show a decided discrepancy. That of May 8 shows a much larger amount of water used per degree difference of inside and outside temperatures than the test of May 20. The tests of May 6 and 19, both made with a gauge pressure of five pounds in the radiator, check very nicely. The water used per hour per degree difference of inside and outside temperatures during the test of May 6 was only about 10 per cent greater than the water used per hour per degree difference of inside and outside temperatures during the test of May 19. Of course, discrepancies must be expected in making tests such as those made at St. Louis and Washington, on account of the great number of factors which are involved.

Fig. 10 shows a diagram on which are plotted the results of the tests of May 5, 6, 8, 19 and 20. Fig. 11 shows a diagram on which are plotted the results of the tests of May 5, 6, 8, 18, 19, 20, 22 and 26. The vertical scale on each diagram shows the number of degrees which the temperature of the steam in the radiator is higher than the temperature of the air in the room, as indicated by thermometers hung about five feet above the floor. The horizontal scale on each diagram shows the number of pounds of steam condensed per hour per degree difference of inside and outside temperatures. A line has been drawn on each diagram to indicate what is the probable relation, as shown by these tests, between the excess of the temperature of the steam in the radiator above the temperature of the air in the room, and the amount of steam condensed per hour per degree difference of inside and outside temperatures.

TABLE 2.

| Date | May 5 | May 6 | May 8 | May 19 | May 20 | May 18 | May 22 | May 26 |
|---|---|---|---|---|---|---|---|---|
| Pressure in radiator | −2½ lbs. | 5 lbs. | 0 | 5 lbs. | 0 | −5 lbs. | −2½ lbs. | 10 lbs. |
| Length of test, hours | 3 | 2 | 2 | 3 | 3 | 3 | 3 | |
| Steam temperature | 203 | 228 | 212 | 228 | 212 | 193 | 203 | 240 |
| Inside temperature | 77.9 | 78.9 | 77.7 | 79.3 | 78.4 | 77.3 | 75.8 | 79.9 |
| Outside temperature | 68.2 | 67.0 | 69.4 | 68.6 | 68.0 | 65.6 | 64.2 | 70.7 |
| Difference between steam temperature and inside temperature | 125 | 149 | 134 | 149 | 134 | 116 | 127 | 160 |
| Difference between inside and outside temperatures | 9.7 | 11.9 | 8.3 | 10.7 | 10.4 | 11.7 | 11.6 | 9.2 |
| Total steam condensed | 15.0 | 18.5 | 12.0 | 22.5 | 17.5 | 15.5 | 16.5 | 18.0 |
| Pounds of steam condensed per hour | 5 00 | 9.25 | 6.00 | 7.50 | 5.83 | 5.17 | 5.5 | 9.0 |
| Do., per degree difference of inside and outside temperatures | 0.515 | 0.777 | 0.723 | 0.701 | 0.561 | 0.442 | 0.474 | 0.978 |

The lines in both Figs. 10 and 11 slant more than the line in Fig. 8, and the line in Fig. 11 slants more than the line in Fig. 10.

The difference between the temperature, 212 degrees, of steam in a radiator at atmospheric pressure and the air of a room at 70 degrees, is 142 degrees; and the difference between the temperature, 228 degrees, of steam at a gauge pressure of five pounds, and the temperature of the air of a room at 70 degrees, is 158 degrees. According to Fig. 8 it is seen that about 10 per cent more steam would be used per hour per degree difference of inside and outside temperatures to maintain this temperature of 70 degrees in the room with steam at the higher pressure of five pounds than would be used with steam at the lower pressure; according to Fig. 10, about 20 per cent more steam would be used at the higher pressure than at the lower pressure; and according to Fig. 11 about 25 per cent

more steam would be used at the higher pressure than at the lower pressure.

The results of the tests made at Washington bear out the results of the tests made at St. Louis, and show a very much greater and more marked saving. In regard to using steam at low pressures there can be but one conclusion drawn from the tests, and that is, that it is more economical to heat with steam at a temperature less than 212 degrees than it is to heat with steam at a temperature greater than 212 degrees. The tests show that the less is the difference between the temperature of the steam in the radiator and the temperature of the air in the room, measured about five feet from the floor, the greater is the economy of the steam used for heating. This economy is not in any way due to the fact that the steam used for heating may have been obtained virtually free of cost, because of having already been used in some other manner before being passed into the radiator, but is due *entirely to the low temperature of the radiator and the steam in it.*

While at work on the tests at St. Louis I did not expect any such results as were obtained there, or as were obtained by Chief Engineer Baird, in Washington, and, therefore, I did not myself make, nor did the committee make, such additional tests as I would like now to make, and which I hope some day to make in order to determine, if possible, to what this economy at the lower temperatures of the steam in the radiators is really due, and therefore the explanation which I am about to offer is one which, while it seems to me to be satisfactory, has not been tested by experiments. After the tests in St. Louis had been completed I hunted through such books and papers on heating as I could lay my hands upon, to find, if possible, something bearing upon this subject. I found that there was nothing bearing directly upon it, but I found an article by Prof. H. Meidinger upon the "Distribution of Heat in Heated Rooms." This article was published in 1897 in the "Zeitschrift für Heizungs-, Lüftungs-, und Wasser-leitungs-technik," and in it Prof. Meidinger gives a description of a number of tests he made with stoves of different kinds to determine which stove was best suited for heating rooms. His tests show that some stoves while heating the air at a distance of about five feet from the floor to 70 degrees keep almost the same temperature at the floor, and at the same time keep a comparatively low temperature at the ceiling of the room. Other stoves would maintain a temperature of 70 degrees at a distance of about five feet from the floor with quite a lower temperature at the floor, and a high temperature at the ceiling. I knew,

from experiments which I have made, that in all heated rooms the temperature increases from the floor to the ceiling, and as soon as I read Prof. Meidinger's article, it at once occurred to me, as an explanation for the results obtained by the tests at St. Louis and Washington, that the radiator at a high temperature probably kept the air at the top of the room, when the temperature about five feet from the floor was 70 degrees, at a much higher temperature than it was kept when the temperature in the radiator was low. The higher is the temperature of the air at the ceiling for a temperature of about 70 degrees five feet from the floor, the greater will be the average temperature of the air in contact with the cooling windows and walls of the building, and, therefore, for a given outside temperature the greater will be the difference between the average temperature of the air inside and that of the air outside; and hence the greater will be the amount of heat transmitted through the cooling walls and windows per hour. As the occupants of heated rooms

TABLE 3.

ST LOUIS TESTS

| Test | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Difference between temperature of steam and temperature of air in room | 83 | 108 | 125 | 139 | 151 | 145 |
| Pounds of steam condensed per hour per degree difference between temperature of steam and temperature of air in room | 0.0547 | 0.0587 | 0.0685 | .0837 | 0.0867 | 0.0847 |

live in that air which is within six feet of the floor, that system of heating must undoubtedly be the best and most economical which will maintain the desired temperature of the room nearly uniform from the floor to five or six feet above it with a low temperature in the upper part of the room; and this is, I think, done by radiators supplied with steam at low temperatures. There are not data enough at hand to enable me to make an assertion as a law or rule for the variation of economy of steam in heating at different degrees of temperature of the radiator above the temperature of the room, as measured about five feet from the floor. I think, however, that the amount of steam used per hour per degree difference of outside and inside temperatures becomes more and more nearly the same as the difference between the temperature of the steam in the radiator and the temperature of the room is increased. This, however, I am not able to state definitely. More tests are needed, and until they are made, all that can be asserted with confidence is, that it is much more economical to heat with steam at or less than at-

mospheric pressure, than it is to heat with steam above atmospheric pressure, and this economy varies with the different conditions under which the heating system is installed and used.

Another question which presents itself in connection with this subject is: How much more, if any, radiator surface should be provided to maintain a room or building at 70 degrees when using steam at or less than atmospheric pressure, than would be provided for steam at a pressure higher than atmospheric pressure?

There can be no doubt of the fact that the greater is the difference between the temperature of the radiator and the temperature of the air in the room, the greater will be the amount of steam condensed per square foot of radiating surface per hour. This is very plainly indicated by the results of the tests made both at St. Louis and at Washington. If anything different from this had been shown the results would not then have been in accordance with the experiments made by other experimenters at other times to deter-

TABLE 4.

WASHINGTON TESTS.

| Date of test, May..... | 5 | 6 | 8 | 19 | 20 | 18 | 22 | 26 |
|---|---|---|---|---|---|---|---|---|
| Difference between temperature of steam and temperature of air in room..... | 125 | 149 | 134 | 149 | 134 | 116 | 127 | 160 |
| Pounds of steam condensed per hour per degree difference between temperature of steam and temperature of air in room..... | 0.0400 | 0.0621 | 0.0448 | 0.0503 | 0.0420 | 0.0445 | 0.0433 | 0.0562 |

mine the heat lost per square foot of radiating surface for various kinds of radiators. In table 3 is shown the number of pounds of water condensed per hour per degree difference of the temperature of the steam and the air in the room for the St. Louis tests; and in table 4 are shown the results as obtained by the experiments at Washington. An inspection of the tables shows very clearly that in both cases the amount of steam condensed per hour increases as the difference between the temperature of the steam in the radiator and the temperature of the air in the room increases. In order to make this more apparent, the results of the tests are plotted on the diagrams shown in Figs. 12 and 13. In Fig. 12 are plotted the results obtained by the tests at St. Louis, and in Fig. 13 those obtained by the tests at Washington. In each diagram the vertical scale represents the difference between the temperature of the steam in the radiator and that of the air in the room; and the horizontal scale represents the total number of pounds of water condensed per hour per degree difference between the temperature of

the steam in the radiator and the air in the room. Although a straight line has been drawn on each diagram through the points representing the results of the tests, it is probable that if more tests, covering a wider range of temperature, had been made, it would have been found that a curved line and not a straight line would have had to be drawn to show the relation between the results of the tests.

On the diagram shown in Fig. 14 an attempt has been made to determine from the St. Louis tests and the Washington tests some relation between the difference between the temperature of the steam in the radiator and the temperature of the air in the room, and the difference between the inside and outside temperatures. The verti-

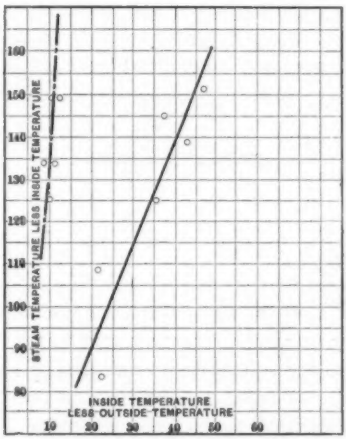



Fig. 14.

cal scale on the diagram represents the difference between the temperature of the steam and the temperature of the air in the room, and the horizontal scale represents the difference between the inside and outside temperatures. At Washington, the difference between the inside and outside temperatures was in the neighborhood of ten or eleven degrees, while in St. Louis it varied from about twenty-one degrees to forty-seven degrees. The dotted line in Fig. 14 indicates the relation between the difference of temperatures of the steam and the air, and the difference between the inside and outside temperatures as shown by the Washington tests of May 5, 6, 8, 19 and 20; and the full line of the diagram shows the relation as indicated by the St. Louis tests. From the diagrams in Figs. 12

and 13 it is evident that more heat is given out by a radiator as the difference between the temperature of the steam and the temperature of the air in the room is increased; and from the diagram in Fig. 14 it is evident that the higher the temperature of the steam in a radiator the higher will be the temperature maintained in the room by that radiator for a given outside temperature. This means then, that a radiator supplied with steam at 212 degrees will not maintain quite the same temperature in a room that the same radiator supplied with steam at a temperature of about 228 degrees, or steam at a pressure of about five pounds pressure by the gauge, will maintain in the same room for the same outside temperature. According to this, then, it seems that in designing a plant it would be necessary to put in more radiating surface if steam at atmospheric pressure is to be used, than would be necessary if steam at five pounds pressure were to be used; and this would undoubtedly be true were it not for another fact which almost entirely overbalances the differences in the results obtained at the higher and lower pressures. Whenever steam is circulated at or below atmospheric pressure it is absolutely necessary, as has been stated before, that the entire system shall be either completely or nearly completely exhausted of air before steam is turned on. This assures that each radiator will be at once completely and thoroughly filled with steam and heated up, so that it at once begins to work efficiently. But when steam is circulated in the ordinary manner at pressures above the atmosphere, the air in the system must be forced out by the steam, and as a consequence the loops of the radiators are slow in heating up, and many become air bound or short circuited, and as the steam cannot then properly circulate they are less efficient in heating. The fact that when steam is circulated in a heating system at a pressure greater than atmospheric pressure, it takes time for the system to get heated up and become thoroughly hot and that the radiations are likely to become more or less air bound, and thus to be made less efficient, is well known to all heating engineers, and to all who have to design and lay out heating systems; and, therefore, a certain allowance is always made for the impaired efficiency of the radiators on account of air in them, in designing a system, and the entire radiating surface is increased beyond that shown by calculation to be absolutely necessary. In the case of a system in which the air is removed by some kind of an exhausting apparatus before steam is turned on, as is done whenever steam is circulated at or less than atmospheric pressure, no factor of safety is necessary on account of danger of the radiators becoming air

bound, and, therefore, the radiating surface need not be increased beyond that shown by calculation to be necessary. We are safe, therefore, in concluding, both from the results of the experiments and from the reasoning based upon what we know to be facts as to the actual working of a system supplied with steam at a pressure greater than atmospheric pressure, that no more radiating surface need be supplied for steam at or slightly less than atmospheric pressure than need be put in for steam at ordinary low pressures in the neighborhood of five pounds above atmospheric pressure. Buildings which are now being heated with steam at about five pounds pressure, may usually without any increase in the radiation surface be heated just as well with steam at or slightly less than atmospheric pressure. In fact it may be possible in many cases where a large factor of safety for air binding has been used in designing a system, to cut down the radiating surface, and heat the building with steam at or only a little below atmospheric pressure, provided a system for thoroughly and effectively removing the air is used.

As every square foot of surface of every radiator, supplied with steam at or below atmospheric pressure, is, on account of the entire absence of air in the system, made efficient, and put always in about the same condition for heating, the exact amount of work which may be expected of each square foot of surface may be determined by a series of experiments; and we can design and proportion the amount of radiating surface required for the building with more exactness than where we know that we must make an allowance, how big we do not know, for the fact that certain parts of each radiator will be rendered more or less inactive and useless by reason of the air which is likely to accumulate in them when steam is used at a pressure greater than atmospheric pressure. Of course, if all the air be taken from the radiators, and then steam at a gauge pressure of about five pounds be used, less radiating surface will be required for the building than would be required if steam at or slightly less than atmospheric pressure be used.

## DISCUSSION.

Prof. Carpenter: I listened to the paper with a good deal of pleasure and it seems to me it is a very excellent paper on the subject. The conclusion, however, is a most remarkable one, and that is that heat can be made to do more work under certain conditions than under others and under conditions which are very different indeed from those which we have considered as established by our previous ex-

perience. It seems to me that it is hardly safe to draw that broad conclusion from the tests which have been presented here. The tests in the first place are short; they do not seem to have been repeated, and as Prof. Kinealy said, there are many things to be looked into before such a broad conclusion should be adopted. Now the general results of the test show that as the pressure in the radiator is increased a less amount of steam was used per hour and that had been pointed out very nicely by Prof. Kinealy. But there is another thing here which has not been explained and which possibly may be explained, and that is that the inside temperatures of the rooms seem to increase with increase of steam pressure. In the case of the lowest vacuum we have 78 degrees. In the case of ten inches vacuum, 84 degrees. In the case of atmospheric pressure, 87 degrees. In the case of five pounds pressure, 88.8 degrees. In the case of ten pounds, 89.4 degrees. In the case of five pounds pressure, 83.1 degrees, which goes back somewhat nearer the other one. These various things possibly may be explained, but, on the other hand, I had not seen any explanation of them. In the case of the Washington tests the results seemed to be rather irregular and do not look like very good work on the part of the experimenters, one way or the other. These are all the suggestions that I have to make. It is a new proposition and a proposition which certainly, if it is accepted, must be on pretty solid ground.

Mr. Warren Webster: I should like to ask Prof. Kinealy as to whether there is any reason other than the removal of the water of condensation and air from the radiator which led to the results which he has explained to us.

Prof. Kinealy: I am not sure that I quite understand the question; but I don't know what led to the results—I simply don't know.

Mr. Webster: I assume that the full efficiency of the radiator was brought about by the removal of the air and water of condensation by the apparatus as shown in your diagram.

Prof. Kinealy: As I state, I think that the difference is due to the fact that at the higher temperature of the steam you have for the same temperature measured head high, four and a half feet from the floor, a greater average outside temperature, and hence the difference between the outside and average inside temperature is greater for the higher pressures.

Prof. Carpenter: Why should you have that with the same radiator? I do not see any reason for that.

Prof. Kinealy: That is on my part a supposition that I have not

tested. It is the only explanation that I can advance. I do know that it is a fact that in rooms heated there is a difference in the temperature at the top of the room and the bottom and that difference depends on the way in which the room is heated and upon the outside temperature in the same room with the same radiators; but whether the pressure in that radiator was or was not the same I cannot say. I have often measured temperatures at various heights above the floor and found that they varied. I could establish no rule for this variation. At some time it was in the neighborhood of half a degree for a foot of rise from the floor up to the ceiling, and at other times it was almost two degrees.

Prof. Carpenter: The point that I do not quite understand is that there does not seem any reason to my own mind why we should expect any greater difference in the air under one condition than under the other.

Prof. Kinealy: Undoubtedly the higher the temperature in the radiator the higher must be the temperature of the air leaving that radiator, rising from the bottom of the radiator to the top, and the hottest air will be at the ceiling. Now we are to maintain a temperature of 70. If you keep a temperature of 70 at any particular point, say five feet, the higher the temperature of the air as it leaves the radiator, it seems to me, the higher the temperature of the air at the ceiling of the room.

Prof. Carpenter: Would it not also be higher at the five foot height?

Prof. Kinealy: No. We are keeping it at 70 at five feet.

Prof. Carpenter: The philosophy of that really is not clear to my mind. That is all. I am much obliged.

The Chairman: Is there any other discussion of this question? I rather think from the remarks that it might be well to continue these tests. I am very sure from experience that we have had in heating below atmospheric pressure that Prof. Kinealy is right so far as the amount of ventilation required. So far as the results of the difference between the temperature of the air at five feet and the ceiling can be explained, that is, why the air is hotter at the ceiling with a high degree of temperature in the radiator than it is with a lower degree, I think that this is a very interesting question, and we might continue it very profitably and make another and further report.

LXVI.

# REPORT ON THE WARMING AND VENTILATION OF SCHOOLS IN ENGLAND.

BY D. M. NESBIT.

(Member of the Society.)

Mr. President and Gentlemen:

Agreeably with your request, I have pleasure in sending you on two sets of plans, which indicate the latest development of the "Plenum system" which my firm (Ashwell & Nesbit, Ltd.) has in-

ELLIS AVENUE SCHOOL, LEICESTER, ENGLAND. TABLE SHOWING CUBES AND AIR SUPPLY.

| FLOOR | No. OF CLASS ROOM | NAME OF ROOM | CUBIC CONTENTS OF ROOM IN FEET | AREA OF INLET IN FEET SUPER. | VELOCITY OF AIR ENTER'G ROOM IN FEET PER MINUTE | ACCOMMODATION | TIMES CHANGED PER HOUR | AIR PER CHILD PER HOUR IN CUBIC FEET |
|---|---|---|---|---|---|---|---|---|
| GROUND | 1 | BABIES | 8,400 | 4.7 | 300 | 75 | 10 | 1128 |
| " | 2 | INFANTS CLASS | 7,000 | " | " | 50 | 12 | 1692 |
| " | 3 | " | 7,000 | " | " | 50 | 12 | 1692 |
| " | 4 | " | 8,747 | 6.0 | " | 60 | 12 | 1800 |
| " | 5 | " | 8,211 | " | " | " | 13 | " |
| " | 6 | " | 8,747 | " | " | " | 12 | " |
| " | 7 | " | 8,400 | " | " | " | 13 | " |
| " | 8 | " | 6,048 | 4.7 | " | 50 | 14 | 1692 |
| FIRST | 9 | CLASS | 8,925 | 6.0 | " | 60 | 12 | 1800 |
| " | 10 | " | 7,963 | " | " | " | 13 | " |
| " | 11 | " | 8,400 | " | " | " | 13 | " |
| " | 12 | " | 8,400 | " | " | " | 13 | " |
| " | 13 | " | 8,400 | " | " | " | 13 | " |
| " | 14 | " | 6,048 | 4.1 | " | 50 | 12 | 1476 |
| " | 15 | " | 8,400 | 6.0 | " | 70 | 13 | 1543 |
| " | 16 | " | 8,575 | " | " | 60 | 12 | 1800 |
| " | 17 | " | 8,400 | " | " | " | 13 | " |
| " | 18 | " | 8,400 | " | " | " | 13 | " |
| " | 19 | " | 8,400 | " | " | " | 13 | " |
| " | 20 | " | 7,000 | 4.7 | " | 50 | 12 | 1692 |
| " | 21 | " | 7,000 | " | " | 50 | 12 | " |
| " | 22 | HALL | | | | | | |
| SECOND | 23 | CLASS | 8,747 | 6.0 | 300 | 60 | 12 | 1800 |
| " | 24 | " | 4,589 | 4.7 | " | 60 | 18 | 1410 |
| " | 25 | " | 8,736 | 6.0 | " | 70 | 12 | 1543 |
| TOTAL | | | 188,936 | | | 1,415 | | |

stalled in this country. The plans sent are for two typical English board schools. The Ellis avenue school at Leicester is a "plenum" installation with downward extraction. The Scarcroft School, York, is a "plenum" installation with upward extraction.

The accompanying tables will give you the numbers of children each school accommodates, and the amount of air given per child per hour. In both cases, the heating is by low-pressure steam, on the gravity-return system. In either school it is possible to warm the whole of the school buildings by using only 1 to 2 lbs. pressure

SCARCROFT SCHOOL, YORK, ENGLAND. TABLE SHOWING CUBES AND AIR SUPPLY.

| FLOOR | No. OF CLASS ROOM | NAME OF ROOM | CUBIC CONTENTS OF ROOM IN FEET | AREA OF INLET IN FEET SUPER. | VELOCITY OF AIR ENTER'G ROOM IN FEET PER MINUTE | ACCOMMODATION | TIMES CHANGED PER HOUR | AIR PER CHILD PER HOUR IN CUBIC FEET |
|---|---|---|---|---|---|---|---|---|
| FIRST | 1 | CLASS ROOM | 8,966 | 5.87 | 300 | 72 | 12 | 1467 |
| " | 2 | " " | " | " | " | 60 | " | 1761 |
| " | 3 | " " | " | " | " | 60 | " | " |
| " | 4 | " " | " | " | " | 60 | " | " |
| " | 5 | " " | " | " | " | 72 | " | 1467 |
| " | 6 | " " | " | " | " | 72 | " | " |
| " | 7 | " " | " | " | " | 60 | " | 1761 |
| " | 8 | " " | " | " | " | 60 | " | " |
| " | 9 | " " | " | " | " | 60 | " | " |
| " | 10 | " " | " | " | " | 72 | " | 1467 |
| " | 11 | ASSEMBLY HALL | 94,520 | | | | | |
| GROUND | 12 | BABIES KINTERG'N | 8,966 | 5.87 | 300 | 72 | 12 | 1467 |
| " | 13 | BABIES ROOM | " | " | " | 60 | " | 1761 |
| " | 14 | INFANTS CLASS ROOM | " | " | " | 60 | " | " |
| " | 15 | JUNIOR MIXED C.R. | " | " | " | 60 | " | " |
| " | 16 | " | " | " | " | 72 | " | 1467 |
| " | 17 | " | " | " | " | 72 | " | " |
| " | 18 | " | " | " | " | 60 | " | 1761 |
| " | 19 | INFANTS CLASS ROOM | " | " | " | 60 | " | " |
| " | 20 | " | " | " | " | 60 | " | " |
| " | 21 | " | " | " | " | 72 | " | 1467 |
| " | 22 | INFANTS MARCH'G HALL | 23,520 | | | | | |
| " | 23 | JUNIOR MIXED SCHOOL RM. | 19,680 | | | | | |
| TOTAL | | | 317,040 | | | 1296 | | |

on the boiler. The boilers in each case are of what is termed in England the Cornish type, i. e., a parallel horizontal cylinder, with a furnace flue fixed eccentrically. The main steam piping in both schools is run on the circuit pipe system, and as shown on the plan in red color. The only pipe that I term the return is that marked in blue, close to the battery II, as shown in the plan of the Ellis avenue school.

As to the batteries, there is nothing novel in these, beyond the fact that they are made of my own design of indirect surface, com-

posed of an oval shaped pipe with a gill or extension around this oval of 3 inches in diameter, fixed at 2 inch centers. These are erected vertically and connected at the bottom with a header valve, so that one valve shuts off several sections to suit the exigencies of the weather. Of course, the heating surface in the schools is not nearly so great as it would have to be in the United States of America for the same size schools, as the outside temperature in your country is very much lower than in England, hence you require from two to three times more heating surface in your country than we do in ours.

A feature in both schools is that the large halls are warmed and ventilated by the introduction of ventilating radiators, which stand over the large fresh air duct, and this supplies air to the radiators. This is rather a novelty of our own, which we introduced for the Leicester School Board, and it has found much favor with other boards in England since its adoption at Leicester. The advantages are, that the large hall is often let for holding public meetings and kindred purposes. When this is so, it is possible to warm the large halls and ventilate them sufficiently for a few hours, during their occupation, without having either the fan or the engine running, which is considered a very good arrangement, as there is plenty of air coming into the fresh air duct automatically, without having the fan and engine running at all.

The hallways and cloak rooms are all warmed by radiators, as it is sometimes found difficult, in strong prevailing winds, to warm up the entrances with the "plenum" system unless a pressure fan be used.

In both schools the fans are of the open-bladed type, non-pressure, fixed in a brick ring and driven by a gas engine (Crossley type). These answer very well and we have had practically no trouble whatever.

My experience of the two schools has led me to believe that, wherever possible, it is best to use the downward extraction, as at Ellis avenue school, in preference to the method used in the Scarcroft School, in which the air is to be taken up and discharged in overhead roof-trunks, it is well nigh impossible to make these sufficiently air-tight, unless a great deal of money is expended.

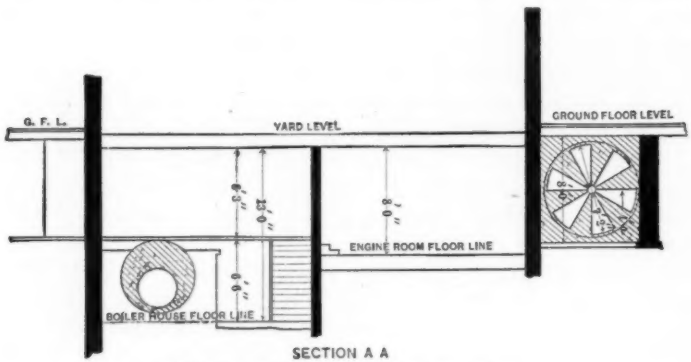
It has been found with some upward extractions in poorly constructed buildings that the prevailing winds have overcome the "plenum" system, and considerable trouble has ensued, and, in some cases, it has been found that a draught has resulted.

I have found, also, that often in taking an upward extraction it

has been impossible to get one tower only for extraction purposes, and when there is more than one extraction shaft or tower, it has been found that the whole system acts like a siphon and the longer leg draws down the shorter leg at times, hence serious trouble. With downward extraction, you get the whole air descending into a common air-duct, and thence up a vertical shaft, which is common to the whole system, and it is practically impossible to get a down draught.

With the bottom extraction, too, it has been found, under certain conditions, that the fan need not be run when once a current of air is established. This keeps the outflow of air going over a considerable time, and it is all that is required in the schools. With upward extraction this is almost impossible.

I have given you these two typical schools, as I thought they would be interesting for showing not only the system I have worked out in England for warming and ventilating of schools, but also the class of schools which are being used in England. The plans are




SECTION A A

BASEMENT PLAN, SCHOOL SCARCROFT, YORK.

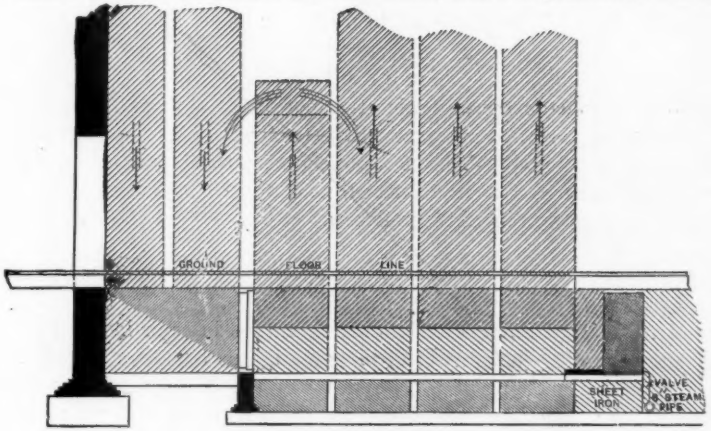
fairly comprehensive in themselves, but should there be any further information which would be of service to the Society, or the members thereof, I shall be pleased to give any further particulars in my power.

I had hoped to have been able to have given you plans of a school heated by open fireplaces, but my time has been so limited and my hurried visit to your country just before Christmas has prevented me from doing as much as I should have liked. If, however, the institution would still like this done, I shall be pleased to prepare one for the summer meeting, or the next annual meeting.

In conclusion, I would like to add that in my opinion, the "plenum" system is undoubtedly the right one to be adopted for warming and ventilating board schools, or where there are a great number of persons congregated for any length of time.

With ordinary or automatic ventilation, it is well-nigh impossible to get that amount of air in to the buildings to keep the place fresh, if the air is not forced in, in large volumes, and warmed in its transit into the buildings.

Another point which wants bringing clearly out with the "plenum" system is, that my experience has been with a well-balanced system such as I have described, that it is possible to make




SECTION A A

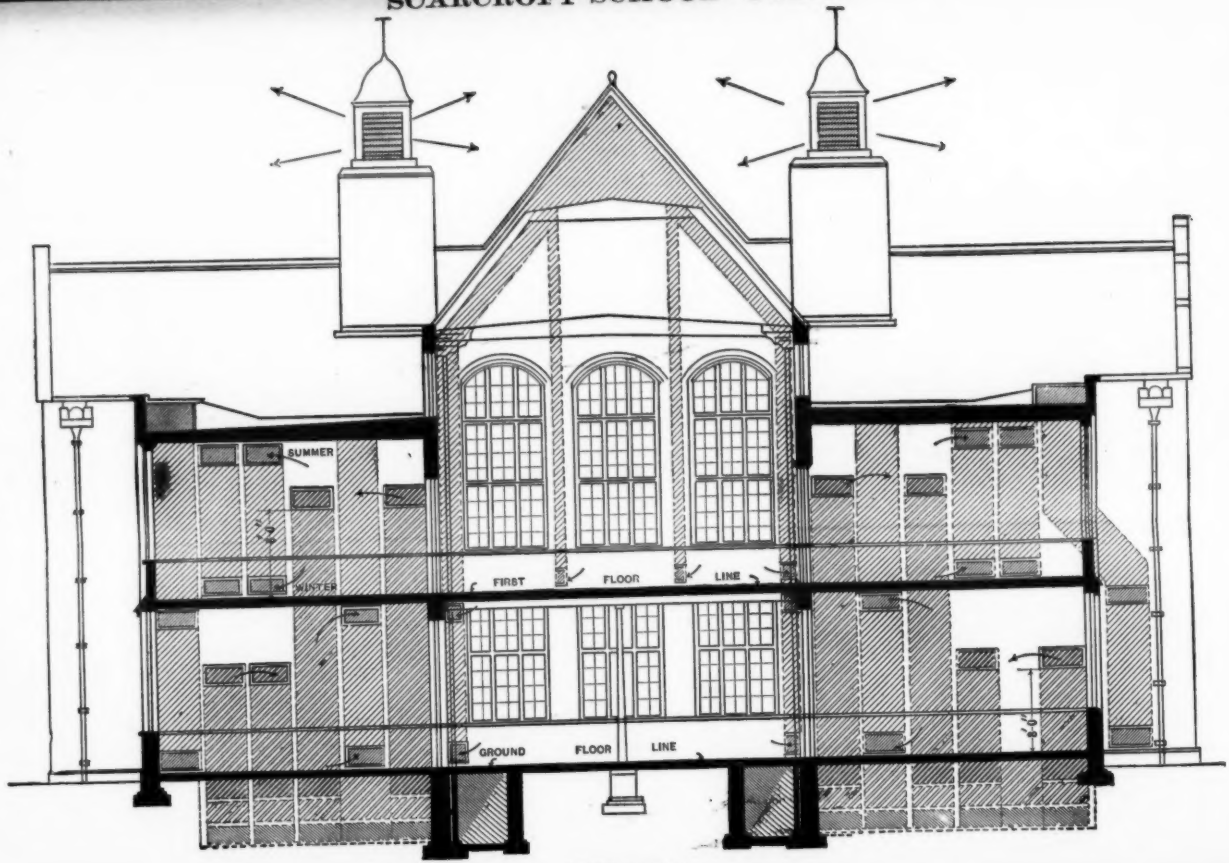
BASEMENT PLAN, ELLIS AVENUE SCHOOL, LEICESTER.

the rooms of more equable temperature than could be done by any other system of warming.

With open fireplaces, you do not get the change of air and the heat is so concentrated at one point, that complaints are frequently heard of the inequality of the heating of the rooms. Heating rooms by direct radiators is, in my opinion, better than fireplaces, but with these there is no ventilation as a rule. The open fire has certainly the advantage of assisting the ventilation of the rooms somewhat because the chimney being warmed takes away some of the foul air in the room, if not all.

Probably the next best thing to a "plenum" system would be ventilating radiators, but these, as many of the members know, are not a success owing to the impossibility of regulating them to the nicety

# SCARCROFT SCHOOL - YORK

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# SCHOOL - S

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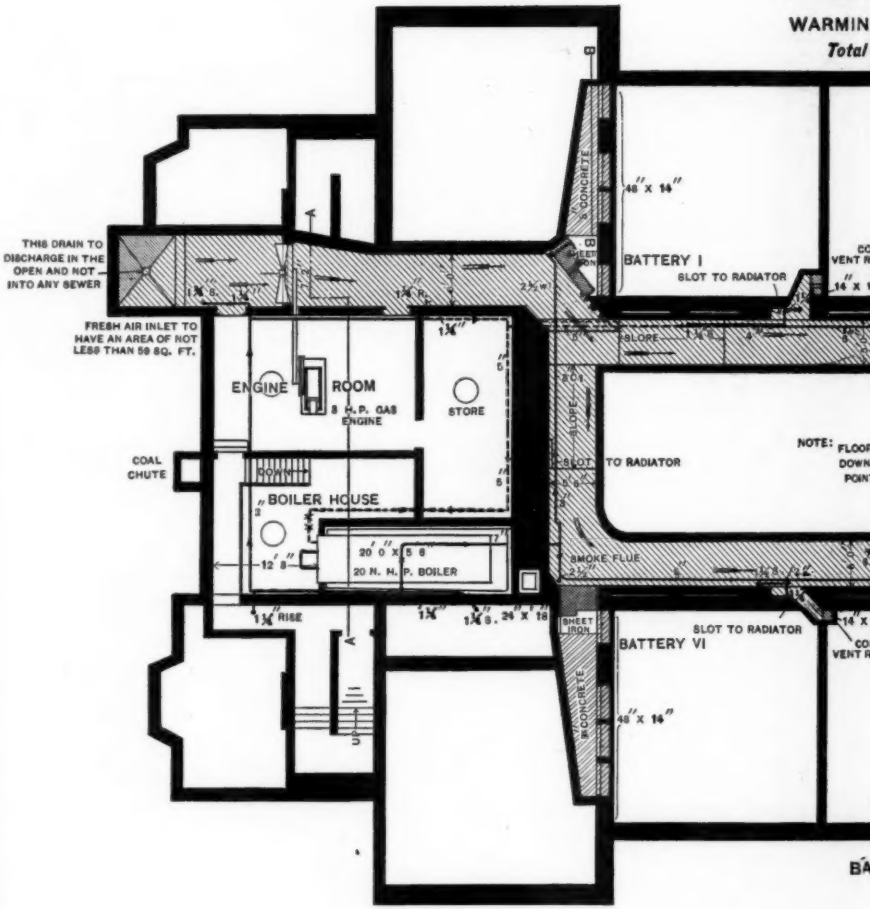


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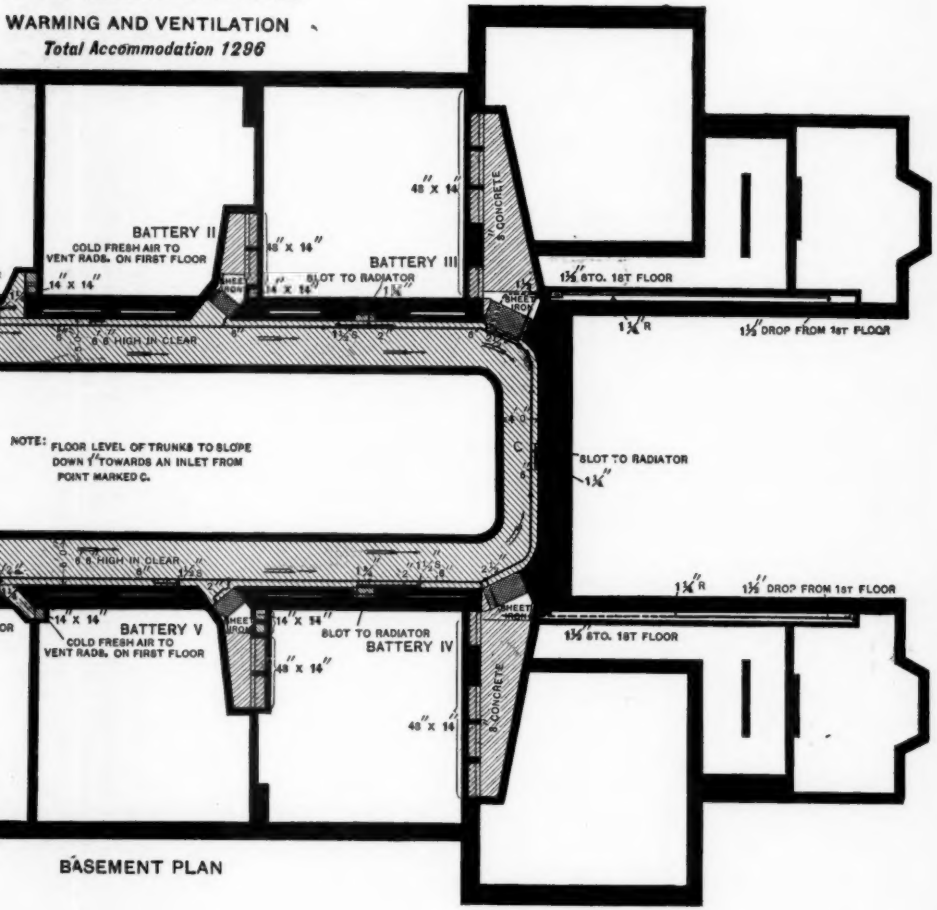
## OR THE YORK SCHOOL BOARD

### WARMING AND VENTILATION

*Total Accommodation 1296*




BASEMENT PLAN

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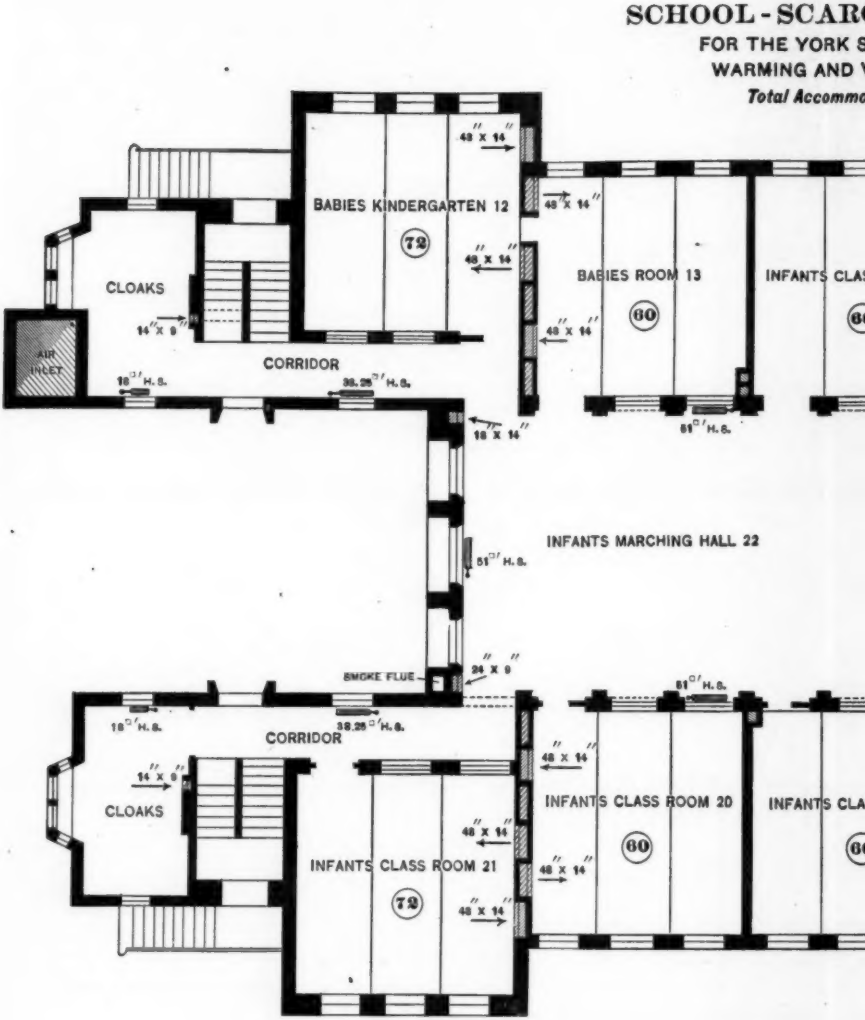


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SCARCROFT - YORK

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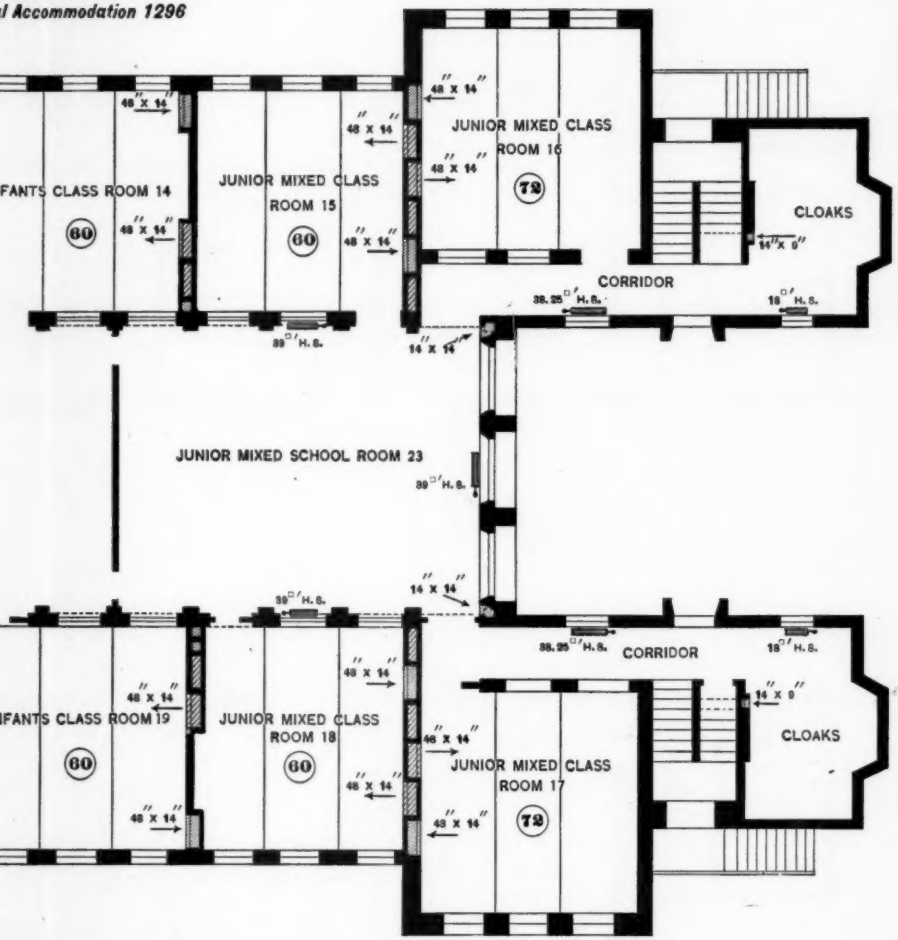
*l Accommodation 1296*




ROUND FLOOR PLAN

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# SCHOOL - SCAR

FOR THE YORK S

WARMING AND V

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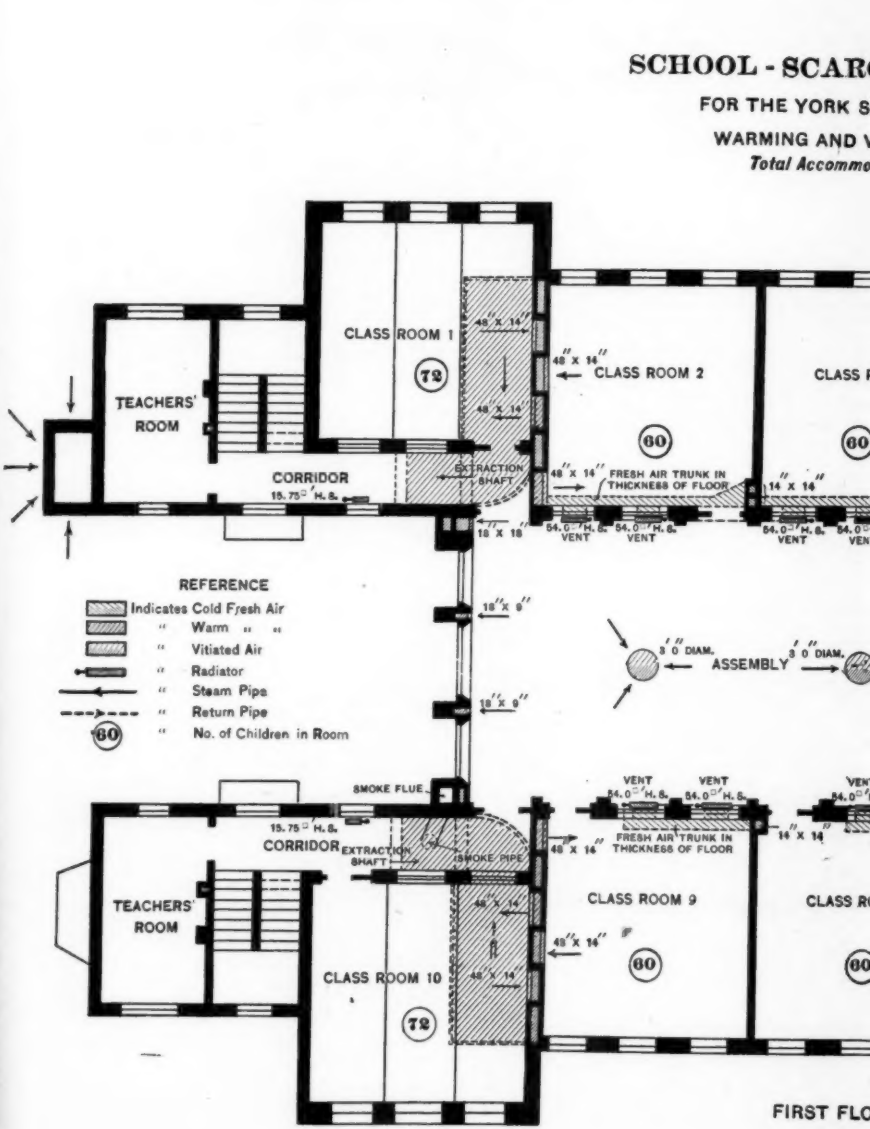


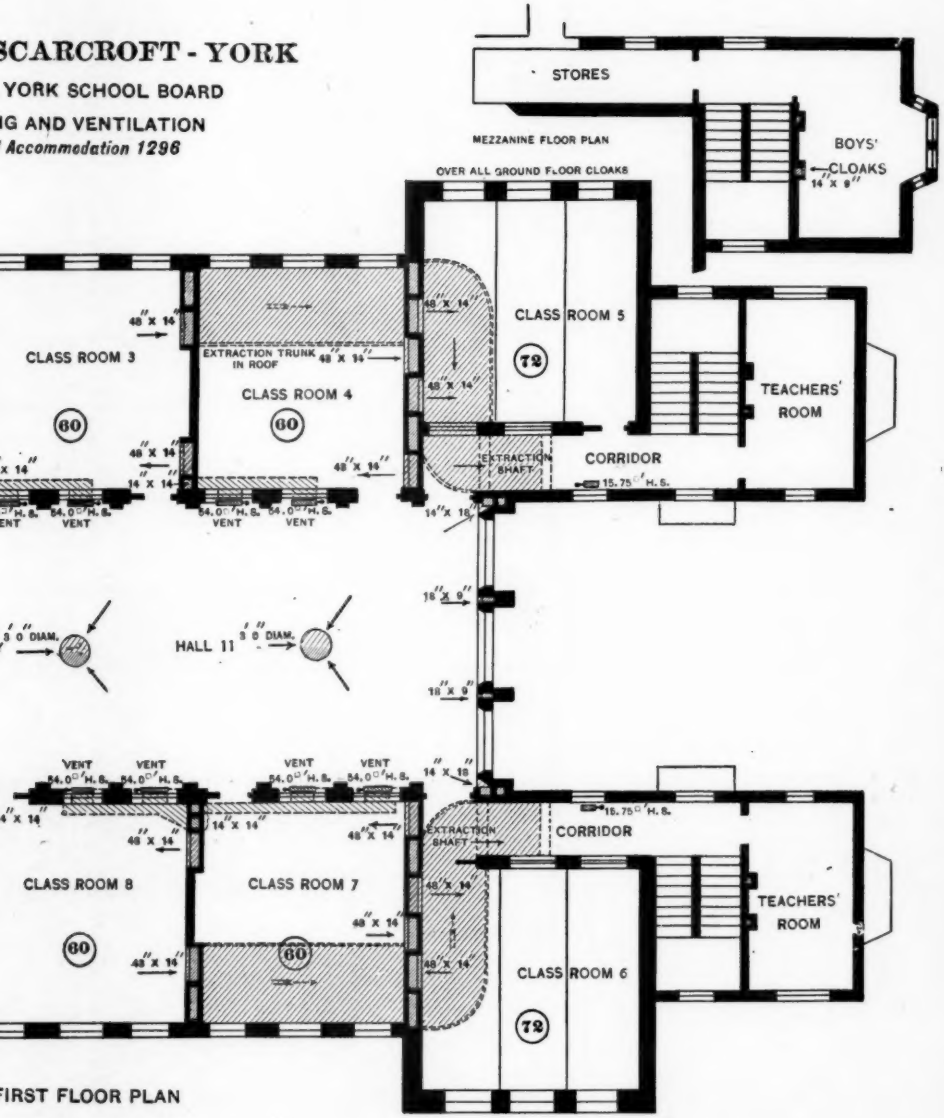

FIRST FLO

# SCARCROFT - YORK

YORK SCHOOL BOARD

IG AND VENTILATION

*Accommodation 1296*




FIRST FLOOR PLAN

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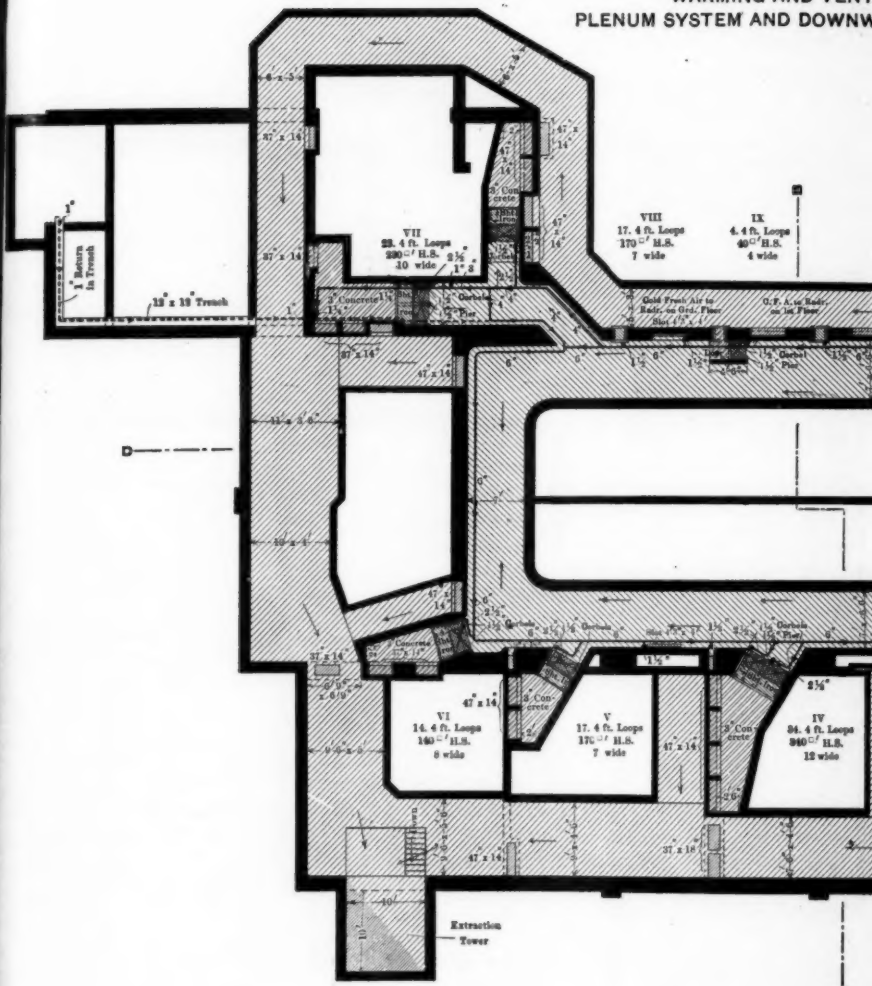
# ELLIS AVENUE SCHOO

## WARMING AND VENT
## PLENUM SYSTEM AND DOWNW




BASEMENT PLAN

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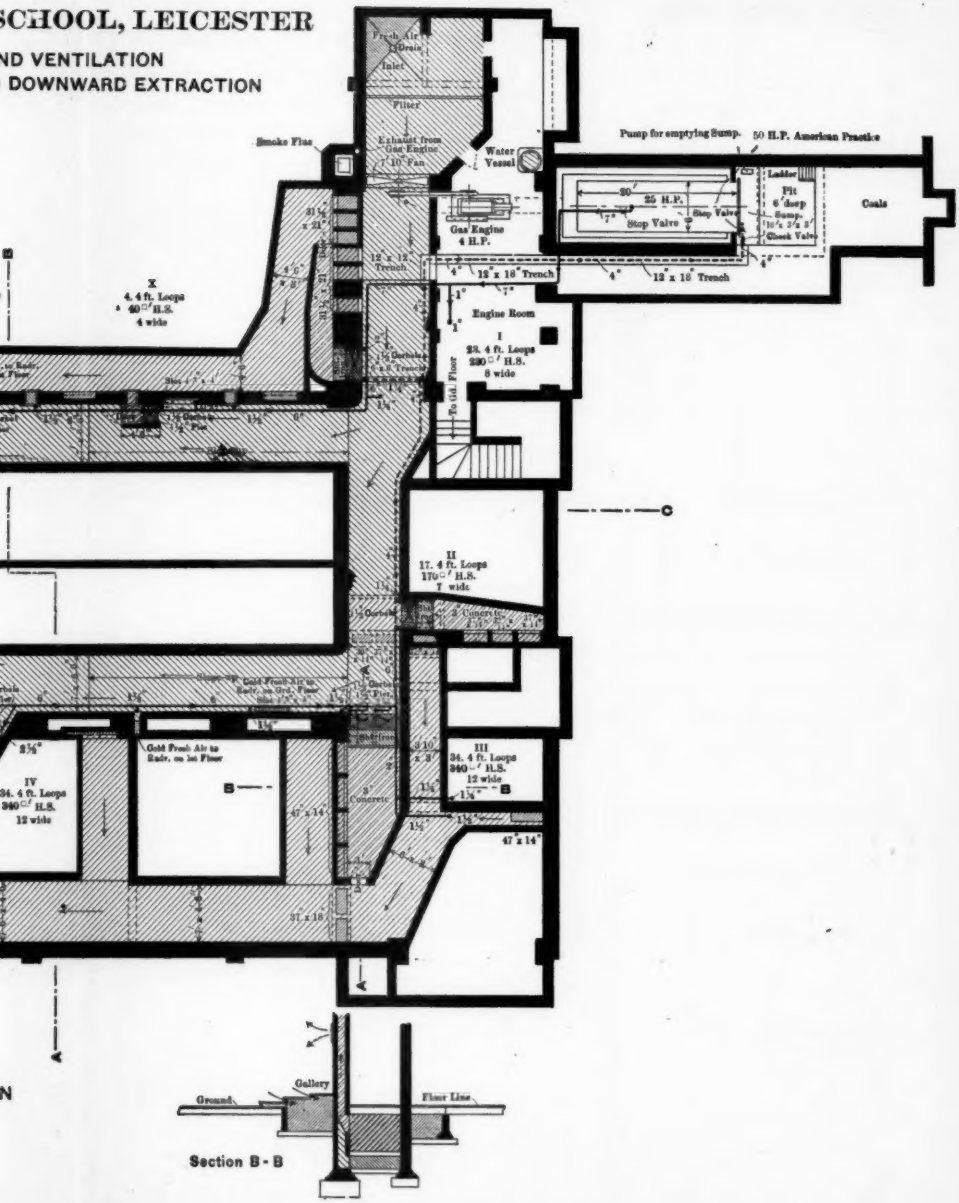
# SCHOOL, LEICESTER

## ND VENTILATION
## DOWNWARD EXTRACTION

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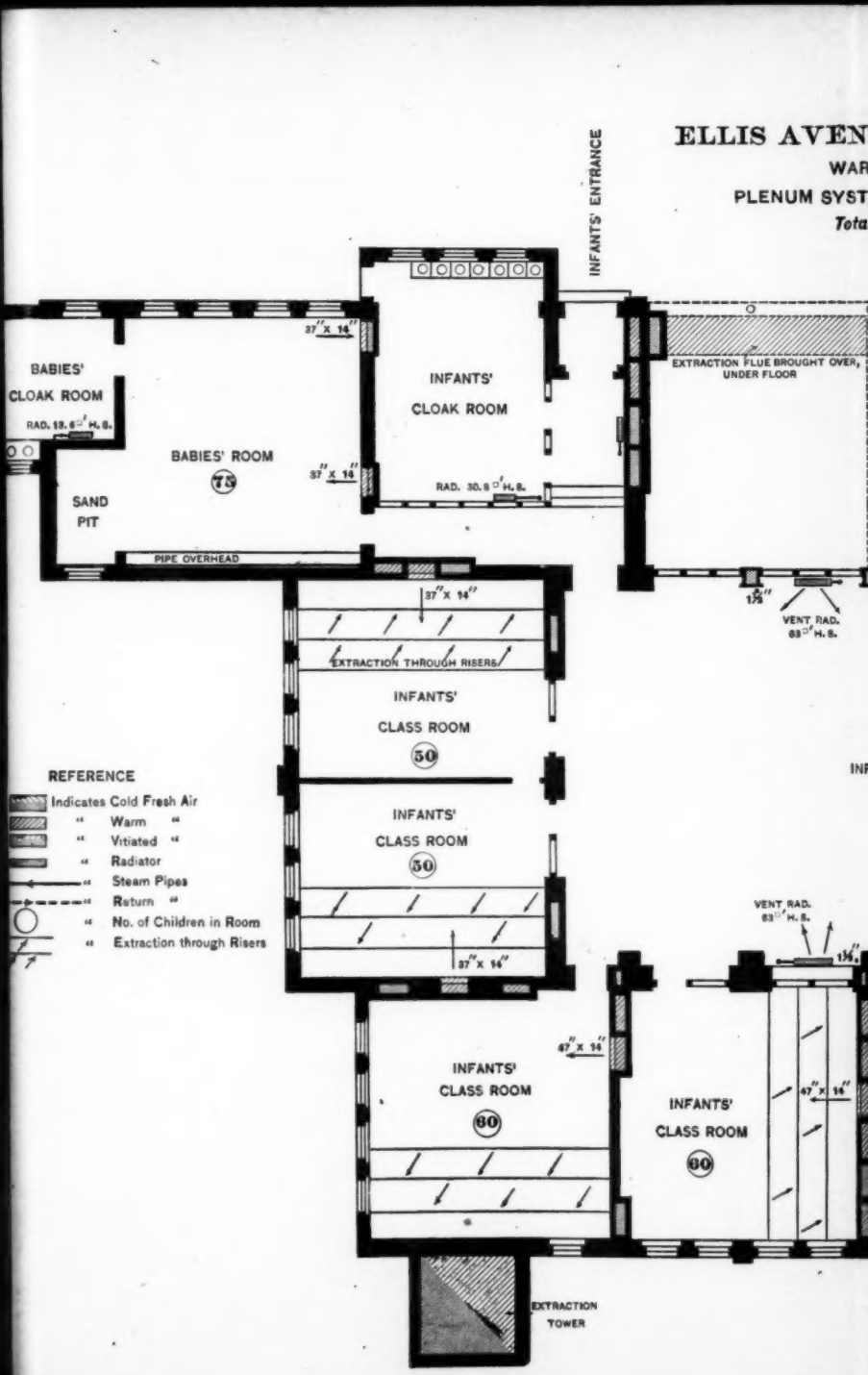
ELLIS AVEN
WAR
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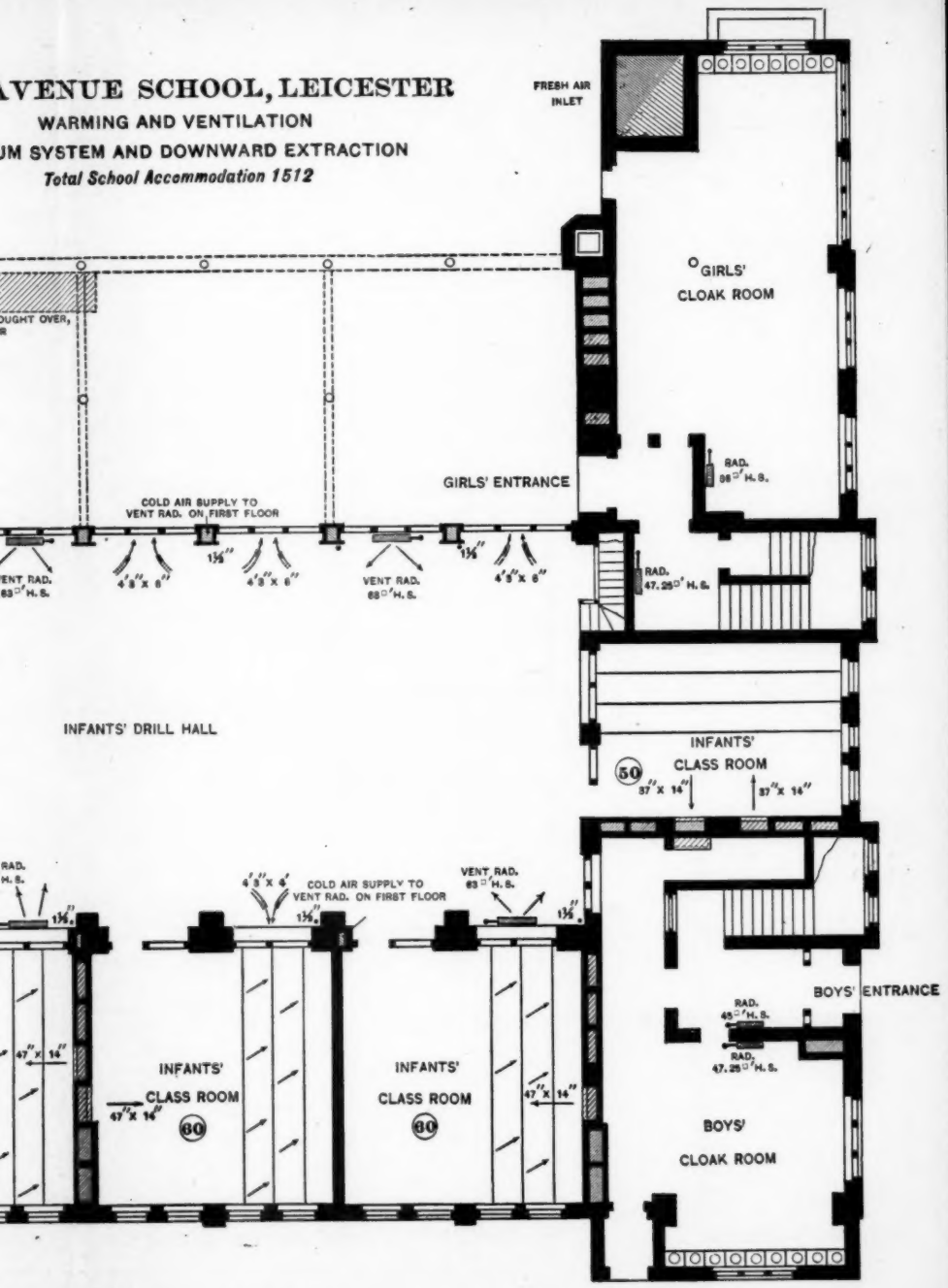
INFANTS' ENTRANCE
BABIES' CLOAK ROOM
RAD. 13.6 □' H. S.
BABIES' ROOM
75
SAND PIT
37" X 14"
INFANTS' CLOAK ROOM
RAD. 30.8 □' H. S.
EXTRACTION FLUE BROUGHT OVER, UNDER FLOOR
PIPE OVERHEAD
VENT. RAD. 83 □' H. S.
EXTRACTION THROUGH RISERS
INFANTS' CLASS ROOM
50
INFANTS' CLASS ROOM
50
REFERENCE
Indicates Cold Fresh Air
" Warm "
" Vitiated "
" Radiator
" Steam Pipes
" Return "
" No. of Children in Room
" Extraction through Risers
INFANTS' CLASS ROOM
60
47" X 14"
INFANTS' CLASS ROOM
60
VENT. RAD. 83 □' H. S.
EXTRACTION TOWER

# AVENUE SCHOOL, LEICESTER

## WARMING AND VENTILATION

## UM SYSTEM AND DOWNWARD EXTRACTION

*Total School Accommodation 1512*




GROUND FLOOR PLAN

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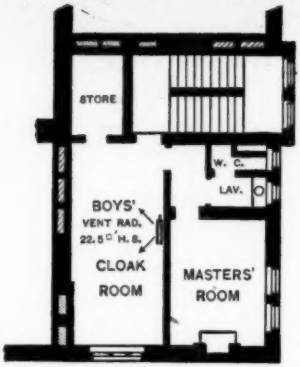
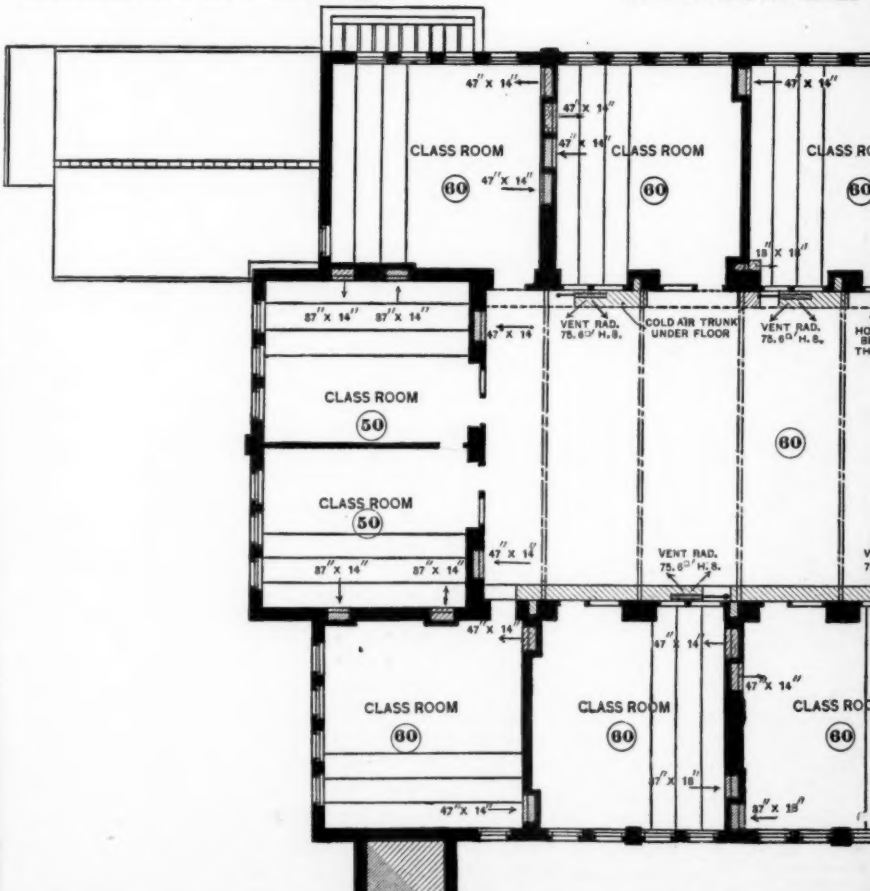



MEZZANINE OVER BOYS' CLOAK ROOM

MEZZANINE OVER GIRLS'




FIRST FLOOR PL

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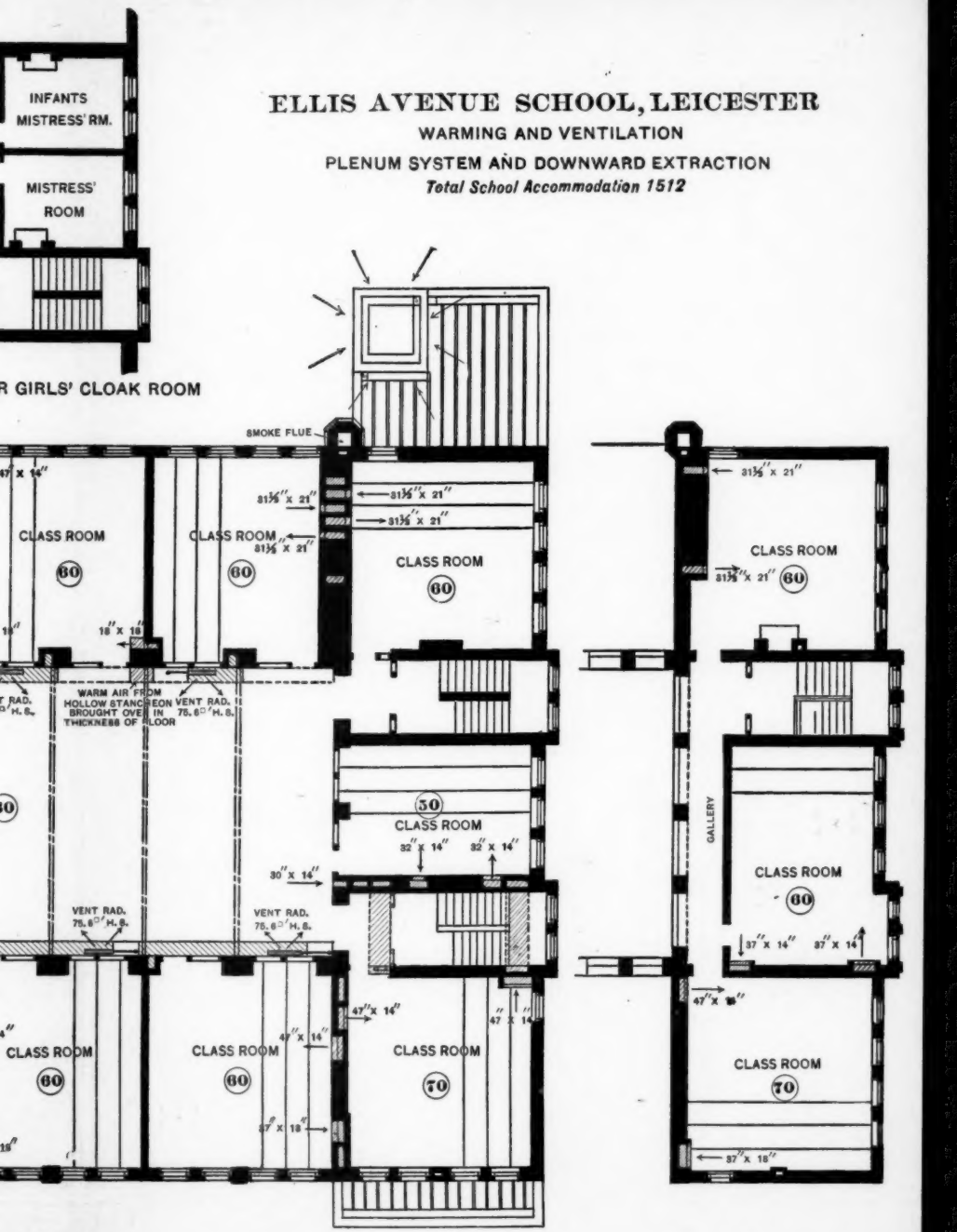
# ELLIS AVENUE SCHOOL, LEICESTER

WARMING AND VENTILATION

PLENUM SYSTEM AND DOWNWARD EXTRACTION

*Total School Accommodation 1512*



## LXVII.

# REPORT ON THE HEATING AND VENTILATION OF SCHOOLS IN SCRANTON AND WILKESBARRE, PA.

BY B. HAROLD CARPENTER.
(Member of the Society.)

### I.—INTERNATIONAL CORRESPONDENCE SCHOOL, SCRANTON, PA.

The building is of stone, with corridors, halls and stairways of enameled brick.

It is not used, as its name might imply, for school purposes, for the pupils are scattered far and wide over the country; but there are many employees in the building.

As I understood they had a very satisfactory heating and ventilating plant, I asked the privilege of examining it, and was very courteously and kindly shown all over the building by Mr. Thomson of our Society, who has charge of the heating and ventilating department in the school.

The heating is done principally by fan and coils, assisted by direct radiation in the corridors, halls and a few of the more exposed places. A blower type of fan in the basement is connected by belt to an electric motor. The heating is all done by steam, which is supplied from the main in street. The heating surface is first a tempering coil, over which the air passes before entering the fan. Coming from the fan, it passes over the condensing or cooling coil (which is necessary where street steam is used), and then over twelve stacks of cast iron indirect radiation. These twelve stacks are built up of three tiers, one above the other. Each tier is divided into four parts. All are valved at feed and return. The twelve stacks on indirect are within a large iron inclosure without top or bottom, which is placed directly over the inlet to the underground ducts which lead to the rising flues at various parts of the building. At the base of each flue is one or more stacks of cast iron indirect radiation, valved. The connection between underground duct and rising duct is made

so that the air will pass over the stacks of indirect or through a by-pass around same, which is controlled by a damper. This damper is operated from the rooms above by a very unique and simple contrivance. At about three feet above the floor level in flue leading to each room is another damper of the butterfly pattern, operated in a similar manner to the one above. This damper controls the volume of air, the other one the temperature.

The entire basement of the building is used, and is in keeping with the other parts of the building. The basement and upper stories are conspicuous for the absence of any kind of piping, the mains and returns being underground.

The warm air is brought into rooms through screens about eight feet from floor level, and is thrown to the extremities of the rooms by deflectors set just inside the screens. Considerable attention has been paid to these deflectors with good results, as they force the warmed air against the cold wall surfaces and thus warm all parts of the room evenly. In winter the vitiated air is taken from the rooms through screens at floor level, or in summer through screens set in the same flue about eight feet above floor level.

A damper easily operated from the room makes the change. All vent flues terminate in the attic, which is used for storage purposes, and keep the attic sufficiently warm for this purpose. At one end of the attic are placed large screens, built into the room to protect them from the weather. On the outside of these screens are placed strips of oiled silk running horizontally, adjusted so that a light wind from without blowing against them causes them to close tightly. At the top of each vent flue is placed a butterfly damper, held in position by a wire connected with a fusible link which melts at 160 degrees Fahrenheit. Should the connection be broken the damper would close the vent flue to prevent the spread of fire. Another point noticeable was that each direct radiator in rooms had two air vents and two valves, although the piping was the one-pipe system. The loop one-third from end had one vent, and the next loop had the other vent, and a blank connection was placed between the two loops. By this arrangement they were enabled to use one-third, two-thirds, or all of the radiation.

The following tests were made by Thomas F. Thomson, a member of our Society, who kindly gave me a copy of same:

On this particular day, October 19, 1898, when the tests were made we had all the dampers so arranged and so set that each room was receiving an equal volume of air, according to its size; said vol-

ume in any case being greatly in excess of that required for the proper ventilation according to the United States authorities.

Test No. 1, Taken Oct. 19, 1898.

*Fan*, 140 inch; ¾ housing; wheel, 84″x42″; mouth of fan, 42″x42″; pulley, 48″; fan revolutions per minute, 72.5; volume delivered against pressure of ducts equals about 12,000 cubic feet per minute, equals 30 cubic feet per minute for 400 adults. There were about 300 people in the building, and the ventilation consequently was about 2,400 cubic feet per hour per person.

The air coming in from outer atmosphere is about 12,500 cubic feet, through two screens 34″x47″ each. The apparent loss of 12,500 — 12,000 = 500 cubic feet per minute between tempering coil and fan mouth can only be accounted for by us neglecting to allow for the slip of the anemometer wheel when taking the high velocity at fan inlets about 600 feet per minute. Air delivery from vent outlets about 12,500 cubic feet per minute; all as measured by the anemometer.

*Motor*, 15 H.P.; pulley, 9 inches diameter; 8-inch belt attachment to fan pulley.

Please notice that the fan was running very easy, and that we have ample capacity even for twice the above number of people.

Steam taken from city mains.

Electric power taken from city lines.

Test No. 2, Jan. 31, 1899.

Fan, 75 R.P.M.

| | | |
|---|---|---|
| Air inlet to fan room ..... | 12,544 | cu. ft. per min. |
| Air outlet; vent opening ..... .... | 10,000 | " " |
| Air outlet; main vent stacks ..... | 8,000 | " " |
| Air outlet; rear vent stacks..... | 4,600 | " " |

Air passing to outer atmosphere through roofs doors, windows, towers and dome. | 20% of the air which has already been employed to ventilate the building.

Plenum pressure, 3/8″ water column nearly.

Occupants of building = 330.

Volume of air per person per hour = $\frac{12544 \times 60}{330}$ = 2,280 cubic feet.

The plant is capable of giving us thorough ventilation for 600 adults with easy running.

### II.—HIGH SCHOOL, SCRANTON, PA.

The Scranton High School building is of fireproof construction, brick and stone, and cost over $200,000.

The sanitaries for both boys and girls, which are placed in the basement, are composed of long iron troughs, flushed and ventilated into a stack warmed by means of steam pipes.

The building is ventilated by two disc wheel fans, one in the basement 10 feet in diameter, driven by a horizontal engine, and one in attic 9 feet in diameter, driven by an upright engine.

The heating is done by steam taken from the main in the street.

The fresh air, which is taken through tower above the roofs, is drawn down into the basement and passed over a tempering coil, then forced through the various underground ducts to the base of the rising flue, where it is passed over one or more stacks of indirect radiation. It then passes up through the flue, and then is thrown into the school rooms about 8 feet above floor level. The halls and corridors are heated by direct radiation.

All radiators throughout the building are controlled by means of electric thermostats.

Each ventilating flue has two openings into the rooms, one at the floor line to ventilate the room during winter, the other near the ceiling to ventilate the room during the summer months.

All ventilating flues open into large horizontal flues in the attic, all of which in turn open into one large flue containing the 9-foot disc fan, which forces the air out through an opening in the roof.

The building has an auditorium with a seating capacity of about 900, and 26 school rooms. Each room has a telephone connected with the principal's room. The fan in the basement is run at 120 revolutions. The exhaust fan in the attic is run at 80 revolutions.

### III.—NO. 3 SCHOOL, SCRANTON, PA.

This new school building contains 12 rooms.

Heating is done by steam generated in a horizontal tubular boiler in the basement.

A fan of the blower type, about 10 feet high, is driven by an upright engine.

The radiation is composed of a tempering coil at fan, indirect stack at base of flues running to the rooms above, and direct radiators in the corridors.

The air passes from fan through underground ducts to the many ducts. The indirect radiation is composed of two stacks, nine sections each, one above the other, for each room. It is arranged that the air can be passed over the indirect stack or around same through a by-pass.

The vent flues are taken from the floor line in the rooms, and terminate in the attic. The attic is ventilated through a cowl.

This building is not yet completed.

### IV.—SOUTH MAIN STREET SCHOOL, WILKESBARRE, PA.

Brick and stone building, containing 590 pupils.

Tests made January 17, 1899:

Temperature air in cold air inlet, 32°.

Temperature air leaving heater, 126°.

Average air in rooms, 70°.

Speed of engine, 150 revolutions.

Amount of air at inlet, 17,550 cubic feet per minute.

Heating is done by steam generated in building by two horizontal tubular boilers.

The fan is run by a horizontal engine.

The radiators are composed of tempering coil, in which the exhaust steam from engine is used.

The heater is composed of 1" pipe divided into five sections, with a by-pass for air around same, and direct radiation in the halls.

The air is carried from the fan and heater through two galvanized iron ducts to the base of the rising flues, one duct for the warmed air and one for the cold or tempered air. A valve at the base of the raising flue controlled by an electric thermostat in the room above admits the proper amount of warmed or tempered air.

Wilkesbarre has twenty schools, with a total of 184 school rooms.

Seven of these buildings, with a total of 55 school rooms, are heated and ventilated by warm air on the gravity system, giving good results.

Nine buildings, with a total of 95 rooms, are heated with steam blowers, direct blowers in halls only.

Three buildings, with a total of 30 rooms, are heated by the steam gravity system, direct and indirect.

One building with four rooms is heated by stoves.

The blower plants have seemingly given better results, and with a somewhat less cost of fuel.

## LXVIII.

## TOPICAL DISCUSSIONS.

TOPIC NO. I.

"What is a safe velocity for steam to travel in steam mains and risers? Is a half-inch valve large enough on the steam supply of small radiators?"

Secretary Mackay: Perhaps we had better divide this topic and discuss the first part: "What is a safe velocity for steam to travel in steam mains and risers?"

Prof. Carpenter: It seems to me that the subject is of sufficient importance to admit of discussion and it is of special importance since the question has been raised lately whether or not in the practice of proportioning main pipes we have not actually used larger pipes than were strictly necessary. The introduction of the low pressures of heating has shown that smaller pipes than had heretofore been used would accomplish the results, and just what velocities can be used in pipes is certainly, it seems to me, a question of interest to all.

Mr. Andrew G. Paul: When I took up the matter of heating I went over the United States to find out what the practice was in laying out heating mains, and I found that there was no uniform standard. One said he had laid out his mains with one square inch of main to one hundred feet of surface, something of that kind, and there were all sorts and kinds of standards; each man was a standard unto himself. I took the subjects up to find out what was necessary, and in designing systems, in the first system in which any experimental work was done, I told the heating men that they could cut the mains twenty-five per cent. One of the largest concerns in the country was afraid to cut its mains twenty-five per cent. But they did get three mains cut down, one at the farther end, some fifteen hundred feet from where the steam was supplied, one in the center of the building and one close to where the steam was supplied. These were feed risers. The job has now been running some five

years and in careful tests that they have made it was impossible for them to see any difference in the working of the system where the risers were cut down. Since that time I have talked with a number and I have found that systems are designed by the leading engineers of the country running from a velocity of as low, some of them, as 15 feet per second, up to as high as 100 feet per second, and with close observation I have been unable to see that the systems that were designed at 15 feet per second were any improvement over those designed at from 80 to 100 feet per second. This, of course, means a wide variation, and I think it is a matter in which a lot of work can be done that will be for the benefit of us all.

Prof. Carpenter: My own opinion is that the velocity ought not to be the factor which determines the size of the steam pipe. I think the co-efficient of friction should determine the size of the pipes, using that, of course, with a certain allowable drop. This is simply my opinion however. I thoroughly believe that all that Mr. Paul says is perfectly true in regard to the matter. I think in many cases the pipes have been put in unnecessarily large, or in other words have been designed for a slower motion than was strictly necessary. That means, of course, using more material than was necessary. I think in all engineering work there is that same sort of tendency; we tend to swing over from one extreme to the other. If in one job we get it a trifle cheap, in another job we do not make that mistake and probably go to the other extreme. That probably accounts for these variations in practice. In changing from our present practice we may make too great a change. So I am not prepared to say what conditions should govern.

Mr. Paul: I find that the condensation that occurs in mains that are put in of large sizes increases the cost of the running of plants to quite a marked extent. That is to say, if you are putting so many pounds of steam through a ten-inch main, the condensation is governed by the size of the main—that is the main condensation—and if a six-inch pipe will do the same amount of work you have a decrease of condensation, and, of course, an increase of velocity. Now there is a limit, but where that limit is I am not prepared to say. I think there is economy in the amount of steam used to supply a building by decreasing the size of the mains alone, leaving everything else out.

Mr. Warren Webster: During the past several years we have had experience with about five hundred and forty-three heating plants with which the Webster System of Steam Circulation was in-

stalled, and as the result of our experience we have adopted the following sizes as feeds:

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ½ | in. | to | 30 | sq. | ft. | of | direct | radiation or equivalent. |
| ¾ | in. | to | 80 | " | " | " | " | " " |
| 1 | in. | to | 150 | " | " | " | " | " " |

for the two pipe systems feeding from mains containing steam at atmospheric pressure.

For the returns of all of the above through which all of the water of condensation and air passes, ½-in. connections are used with ½-in. Webster Thermostatic Valves attached thereto with each unit of radiation. A partial vacuum is maintained within the return lines varying from 4 to 10 ins., according to conditions, which vacuum communicates from all various return lines to the delivery side of each of the Webster Thermostatic Valves.

Mr. D. M. Quay: About three years ago I designed a plant that had about 22,000 feet of radiation in it, an overhead system with a ten-inch riser. I remember Mr. Paul criticised my size. He thought it was too small. We used to use a great deal larger than that, but we have been gradually reducing them. One reason that the pipes used to be carried larger than they are now was on account of the increased back pressure in the system of small piping, where we have to have about five pounds pressure in order to get a proper circulation; we found that by increasing the size of the pipe we could get a circulation with two pounds pressure. That was found by actual experience. I think that is one reason we used larger pipes than we have been using since the vacuum systems have come in vogue and since we have found the benefit of heating at atmospheric pressure. So that when I laid out the ten-inch riser for 22,000 feet I was not much afraid of it, because I had been making tests and felt I was pretty safe. But I remember Mr. Paul said he thought my riser was a little too small. I guess he would not say that now probably, especially if it had the Paul system on.

Mr. Paul: There is another man who took considerable exception to that same plant.

Mr. Quay: I did not put the plant in, so if they had trouble with it I did not have to stand it. I noticed recently a job laid out on the overhead system with 32,000 feet and a nine-inch riser. It made me a little shaky as to the result. I remember how I was criticised for only having a ten-inch main for 22,000 feet, and when I found 32,000 on a nine-inch main I thought it was going farther than I cared to go. I have once or twice refused to figure on a job where I thought the pipes too small, and I have been criticised about it

quite lately, and I may be mistaken. That is one reason why I like to have the question discussed. Of course, as Prof. Carpenter says, the velocity of the steam is not the only question. Of course as you increase the velocity and decrease the size of your pipe you increase the friction. It takes power to overcome friction. It does not take as much power to overcome friction with a vacuum as it does under pressure. I am making that statement without having the figures to verify it. We will have Prof. Kinealy and some of the experts make a test and report, I hope. I think, however, I am safe in making that statement, that with a vacuum, pulling the steam through a pipe, it does not require as much coal or as much cost to overcome the friction as it does if you are forcing steam through the pipe. There is one objection to high pressure, and that is the noise in the steam pipe, and again you do not have the same noise in the steam pipe at a high velocity with the vacuum that you have with pressure. That is another question. That I think I am safe in saying, and I think by experience you will find that is the case, that you do not notice the noise from the friction as much if the circulation is being caused by a vacuum as if it is being caused by the pressure. There is an advantage however, I think, from a commercial standpoint—I know there is—in reducing the size of pipes. We want the pipes large enough to do the work and do it economically. We must not leave out of view the question of the amount of coal it takes to circulate steam. We must not reduce our sizes so much that we are going to lose economy on account of this friction, unless we have something to overcome it. When we have the pipes large enough to accomplish the best results, then we must consider the point from a commercial standpoint. It is not a question alone of a large pipe, but it is a question of space. You find any man who is building a building will figure on the square feet of floor surface in his building as being valuable. You put fifty pipes in a sixteen story building and a small increase in the size of each pipe will amount to a good deal before you get through with it. We make that same argument to show an advantage of the one pipe system over the two pipe system—the question of space, not only the actual floor space, but the room in the office, the space for setting a chair or anything else. They figure very carefully, these times, on the number of feet of floor space they have to rent. When a man is considering the question of putting up a building, with the price of pipe what it is now, of course he does consider very carefuly the number of feet of pipe that are to be put in that building. I found recently in making a calculation that pipe alone costs twenty per cent. more than a

radiator costs; that is, to make a coil, and we used to think we could put in a coil cheaper than a radiator. But we find that inch and a quarter pipe without any fittings or labor on it costs twenty per cent. at least more than cast iron radiation. So when we find pipe that high we do not wonder that any person who can reduce the size of pipe without impairing the job is going to do it.

Mr. Paul: Referring to what Mr. Quay says about being shaky, I would always rather be on the safe side than any other way. I remember the building he refers to, and there was quite an exception taken to the building by one of our members. But the main went in and the job has always run satisfactorily. But when you come to take 32,000 feet I find that the velocity would be about ninety feet per second on 22,000 feet for a ten-inch main and the velocity on a nine-inch main for 32,000 feet would be 160. Now if we are going to jump from fifteen velocity to 160 velocity, it can be done; but I don't know whether it is policy to do it or not.

Mr. James Mackay: I would like to ask if you know that a nine inch riser was put in on 32,000 feet of radiation and did its work?

Mr. Quay: It is not working yet. It is not done. It is being put in.

Mr. Warren Webster: We have at our factory, in my office, two radiators, sixty inch each, which are fed with a half-inch supply; a half-inch feeding sixty feet of radiation. We run our system at the atmosphere to half a pound, all winter. The coldest days in the winter we open the window so as to increase the condensation as rapidly as possible and we have thermometers on the radiators top and bottom. To demonstrate the efficiency of the system the coldest days last winter we filled those radiators with steam at atmospheric pressure with a half-inch supply. We do not advocate a half-inch supply on 60 feet radiation; we limit it of course. In our system there is a big factor of safety of a half-inch to 30 feet, and so on. But these tests demonstrated the fact that the quantity of steam supplied to fill that radiation could be taken through a half-inch pipe with six-inch vacuum on the return back of the thermostat valve, making sure to remove the water and air of condensation from the radiator. That is in actual operation all the time right in our office. No change has ever been made since 1893, six years ago. They are there yet.

The Chairman: Is there any discussion of the second part of the topic?

Mr. Paul: In regard to small valves, taking the second part of the topic, I made a very interesting experiment some two years ago

in a building where they had the Johnson system of thermostatic regulation, and the valve happened to be in such shape that the Johnson valve was out of order. It was a one pipe job, and I wanted to see, if possible, the flow of the water of condensation back through the supply to see whether it went back uniformly or fluctuated, and I took a common gauge glass, pressure gauge, three and a half inch dial, took the glass and laid it on top of the valve, intending to look down into the valve and see the water flow out in the radiator. The radiator was cold at the time, and of course there was no pressure on the building and we were circulating steam a little below the atmosphere. Up to the time the radiator filled with steam that glass was covered continually with patters of rain, showing that although the velocity was into the radiator, the moisture in the steam, the water, came right straight up and spattered on the glass, so that you could see rain spattering on the glass. I kept watching it very closely, because I desired to see the condition of the radiator, and almost instantly that glass colored, and I said to the young man standing there, "That radiator is hot," and he put his hand on the radiator and found that every part of the radiator was hot. Instantly, as quick as the radiator became hot, the velocity was reduced to such an extent that the patters of rain did not come on the glass and I could look down in there and see that water flow just as perfect as anything back out of the radiator. That shows that when we increase velocities at the supply of the radiator the water goes in a straight line, the steam may turn into the radiator, but the water goes in a straight line up. It may go some three or four inches out of the regular line of travel of the steam. It also shows the difference in the velocity of steam flowing into a radiator between the time of first filling and after the radiator is once filled. There is no question in my mind but that if we are going to increase our velocities to a large extent we have got to be very much more careful in the way we drip our mains, for the reason that water of this velocity will go in a straight line irrespective of the steam that may go up the risers. The water will go straight ahead and will strike against any fittings and spatter and increase the condensation under those conditions. But I know of course in tests that I have made that after the steam has once filled the radiator the size of opening can be reduced a great deal, but up to the time it has filled the radiator I do not think you can reduce it—not to the point that some have been reduced.

Secretary Mackay: What is the size of the connection of the radiators?

Mr. Paul: The radiator was sixty feet and had an inch and a quarter connection.

Mr. James Mackay: The radiators that Mr. Webster speaks of were two pipe connections.

Mr. Webster: Yes, sir; feed and return.

Mr. George E. Adams: What was the length of the half-inch feed?

Mr. Webster: About four feet from the riser.

Mr. Adams: What was the size of the riser?

Mr. Webster: Inch and a quarter let-off connections.

Secretary Mackay: I would state that in the early applications of the Holly system, while they did not return the water to the system of heater, they frequently placed radiators as much as fifty to sixty feet with half-inch steam supply and half-inch return and an open end to the atmosphere, and the radiators were made of tin leader pipe with cast iron base and top bolted together, so that with that very strong condensing surface the half-inch pipe under their conditions seemed ample to supply their radiation. The way they operated it they did not even use the full half-inch pipe. They merely opened that half-inch radiator valve until vapor would begin to rise from the open end of the half-inch pipe on the other end of the radiator. It was a T connection on the end of the radiator. That seemed under all conditions of temperature to be sufficient to maintain uniform temperature in the radiator.

Prof. Carpenter: Were the radiators noiseless?

Secretary Mackay: Well, no. There was a little rumble.

Mr. Webster: I should like to ask Mr. Mackay as to what pressure was carried in the feed up to the valve which led to the radiator.

Secretary Mackay: They carried a pressure on the system usually anywhere from 15 to 25 pounds. But coming into the building there was a reducing pressure valve placed, and the average pressure of the building was about a pound and a half to two pounds on the inlet inside the building. This was back in 1880.

TOPIC NO. 2.

**"What is the relative fuel economy of heating with steam or hot water of low pressure and temperature?"**

Mr. Paul: I would ask if anybody has any data as to the actual amount of heating per square foot of heating surface at any pressure for twenty-four hours? That brings the question down to what would be the relative cost per square foot of heating surface for heating buildings for twenty-four hours under any given conditions.

If we have any data of that kind it will start the discussion. I can say that under our system we have buildings that are heated at half a pound of coal per square foot of heating surface, twenty-four hours. There have also been reported other buildings that were heated under other systems, some hot water, where it has gone up as high as three pounds of coal per square foot of heating surface, twenty-four hours. Now in order to get the relative economy, it must be, it seems to me, based on the amount of coal consumed to heat a given building for twenty-four hours per square foot of surface.

Mr. Wolfe: I do not think that a general comparison on that line would be right, because excepting it was made in the same building, under the same exposure, it would hardly show the relative value. We all know that the situation of the building has much to do with the coal consumption as well as the heat and condensation. I would suggest that this would be a good topic for our committee on tests possibly to gain all the information they could and report at the annual meeting, because it would interest us all.

Mr. Paul: In answer to Mr. Wolfe, I would say that it would seem to me we must start at some standard. The building I speak of is a building of twelve stories that is closed on all sides and the temperature went to 3 below zero and averaged five during entire days of twenty-four hours, and the temperature was kept in the entire building by the Johnson system of thermostatic regulation or a similar system, at 70, and we got a uniform condition.

The Chairman: Do you know the amount of radiation?

Mr. Paul: About 21,000 feet. I would say in order that there be no misunderstanding that there was only fifty horse-power of exhaust steam. The other building was a United States building with very thick walls, in Washington, and it was heated by hot water, so that it was where the temperature does not get down very low. But I would say, gentlemen, in order to give you a little more light on the subject, that I have made tests where the radiating surface placed in a building was not sufficient to heat the building properly. For instance, I know of one case in which there was something like 11,000 feet of heating surface specified for the job and the steam fitting contractor put in 5,500. In consequence when we tested that job it took a pound and a half per square foot to heat twenty-four hours under the same conditions. So that I realize what Mr. Wolfe says in regard to conditions, and if you do not put surface enough in a building it will take a great deal more per square foot of surface.

Prof. Kinealy: I take it that the question refers to the ordinary

steam plant using steam in the neighborhood of five pounds, say, and a hot water plant using the open system in which the hot water is under 180 or 200 degrees any way. Now there was a time, not very long ago either, when most of us thought that it was more economical to heat with hot water at a low temperature than it was to heat with steam at pressures in the neighborhood of five pounds by the gauge. Moreover there were tests made which seemed to bear out that supposition. I do not remember now the years when they were made, but there were some tests made in Michigan. Again, there were tests made in Massachusetts to determine whether or not the hot water at the low temperature was more economical than steam at ordinary pressures of about five pounds. Both these tests show a very decided economy in favor of the hot water. About 1891 or 1892, I think it was, there were some tests made at Cornell University. Prof. Carpenter can probably tell you more about them than I can. I think, however, they were made under the direction of Prof. Bailey, the professor of horticulture. Those tests show that there was no difference in economy between the hot water and the steam. Now that rather closed the subject, but I think that it should be opened again in view of the facts which I got at St. Louis, and which were gotten down at Washington by Mr. Baird. It seems to me that it is time to open the subject again and not consider it closed by the tests made at Cornell.

Prof. Carpenter: In regard to the matter to which Prof. Kinealy refers, I might say that I had charge in a certain way of the method of making tests both at Michigan and at Cornell; that is, I was at Michigan at the time the tests were made and took immediate direction of the making of the tests, although they were done in other departments. The same is true of the tests at Cornell. I was familiar with the conditions in both cases and the results were as he says. The results of the Michigan tests were, I believe, given in a paper read by me before the American Society of Mechanical Engineers. Before that similar tests had been obtained in Massachusetts. I believe the Massachusetts tests were afterwards repeated with the same results. The Michigan tests were, after I left there, repeated with the same results, that is, showing a decided difference in favor of the hot water. But I believe in both the Michigan and Massachusetts tests, the entire difference could be accounted for by the difference in flue temperatures of the two boilers. That at least was my conclusion, and it was the conclusion also of the other people who looked into the matter. The same thing might also perhaps explain the results of the Cornell tests. In the Cornell

tests, which were made with hot water, the heater was small for the work. That is, they put on more surface than they should have put on considering the conditions. The chimney was very small. In fact they had to put the heater on to a chimney which had been built for a stove, and rigged up a little place which was very inconvenient and not well suited for the heater, and the result was that the chimney temperatures of the hot water heater ran high and ran higher than they should have done, simply because there was very large waste of coal due to the character of the combustion. I never made any record of the matter, being busy with other things, but Prof. Bailey did not like hot water any way for other reasons and he would not take anything into account only just the actual facts. The result was that his report as he gave it and the facts as they existed did show decidedly against the hot water, but the reason was the way he had the hot water heater set. I do not think it would have shown in that way if the hot water had had what I might consider a fair treatment.

Mr. George E. Adams: About twelve years ago I wanted to put heating apparatus into my store building. We put in steam. At that time I was not much of an advocate of hot water. At the same time I fixed it so that by changing the piping a little I could test it for hot water also, and we operated it through the winter with steam. We used perhaps eight or nine hundred feet of radiation and kept a record at that time, but not a permanent record, and then used it the following year with hot water, keeping the record and comparing it. While I do not remember the exact conditions, the result showed that with the hot water we could maintain the temperature of the store for twenty-four hours easily through night and over Sunday, but with steam our temperatures would drop off in the night. I had very good data on the question of economy of fuel at that time, but do not recollect what it was, except in a general way. I found that we were heating the store with hot water at a consumption of about two-thirds the amount of fuel that we used to heat with steam, the plant being identical in every respect except that the circulation through the piping was changed a little bit in using the hot water. The conditions, though, were as favorable in circulation for one as the other system, so that we finally decided to use the hot water entirely and have been using it for about ten years continuously. I just offer that as a general idea of what can be done.

Mr. Paul: May I ask Mr. Adams what pressure he used on the steam and what temperature he used on his hot water; average temperature and average pressure?

Mr. Adams: The temperature of the hot water is ordinarily about 180 degrees. In extremely cold weather we have run sometimes as high as 200. The outside temperature in that place sometimes falls to 40 degrees below zero. At the time we were making the tests with hot water we had a spell of weather where the temperature dropped below zero and for two weeks not a day was above zero. The highest temperature of water I think was 200. The steam pressure that we carried was from two to three pounds in extreme cold weather. We never had to force the apparatus. Our boiler was very large for the amount of work it had to do in both cases and the circulation was very easy.

Mr. Webster: Mr. Chairman, Mr. Paul has given us an account of his test, in which half a pound of fuel per square foot for twenty-four hours was the basis. He also stated that in that building there was about 50 horse-power of exhaust steam. It is very evident that that 50 horse-power of exhaust steam would not have filled the quantity of radiation that was in the building. Now I should like to ask Mr. Paul was that half pound of fuel based on the additional quantity of steam required to supplement the exhaust, or did it represent the cost of generating the entire amount of steam used in the heating apparatus?

Mr. Paul: The building that I mention was the Milwaukee City Hall. The test was published in our proceedings some two years ago, so that any one can take the test up and see the exact amount of coal used for twenty-four hours and the exact amount of heating surface, the wind and the average temperatures for three days' run, and the coal; he can see the entire amount of coal used for power and for heating the building. The outside temperature averaged in one test, without the system, at 18 above, and the second test, with the system, averaged about 12, and the third test with the system averaged about five above zero for twenty-four hours. It seems to me that the whole question resolves itself into the question of temperature. That is to say, the question of steam or hot water is not the question, but the question is as to the economy of the temperature. I think you will find the same economy in circulating steam as in hot water if circulated at the same temperature.

Secretary Mackay: It would seem to me that the report of Mr. Paul would hardly be a fair comparison, unless the ratio of the radiating surface for steam to the building and the ratio of hot water to the building were stated, because a large amount of steam and a small amount of hot water would give those results. My experience in placing steam appartus and hot water apparatus in the same building

is that under exactly the same conditions hot water does show a marked economy of fuel, and I have in mind an apparatus now that was placed in the best possible manner advocated by some of our members for steam. The apparatus was operated, and removed and replaced by hot water in such a way as to give as good results, or the owners say better results, and certainly greater economy.

Mr. Wolfe: I think, Mr. Chairman, that this subject could be properly subdivided into three parts, that is as pertaining to residential work, as to the warming of large buildings, and as to the warming in connection with ventilation. Of course in residential work my judgment is that hot water is the most economical in dollars and gives satisfactory results, for the reason that when you warm the water approximately two or three degrees your circulation begins, and you are utilizing in radiation everything from your feed-water temperature, or within two or three degrees of your feed-water temperature up to as low a temperature as you can circulate steam on the vacuum principle, and your gain is between the feed-water temperature and that degree. Again, in steam you begin to lose from that degree back to your feed-water temperature. But I think it is a subject we would all like to know about, and if it is in order I would like to move that the committee on tests be requested to gather such data as possible in connection with this topic and report to the society.

Secretary Mackay: I would say that the building I refer to was a very large public building with plenum fans on the inlet and exhaust fans on the outlet.

Mr. A. A. Cryer: I would like to ask Mr. Mackay what was the temperature of the steam and what was the temperature of the water on the tests he has reference to.

Secretary Mackay: The first steam apparatus was intended as a low pressure apparatus, but had frequently to be run at what we would not consider low pressure, that is up to ten or eleven pounds, in order to get results. The later steam apparatus was a vacuum system, working under a vacuum or partial vacuum, and the hot water system was run at a temperature never to exceed 200 degrees, but more generally run at about 180 degrees temperature.

# CONSTITUTION.

### NAME AND OBJECT.

The name of this organization shall be "THE AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS."

Its objects shall be the promotion of the arts and sciences connected with Heating and Ventilation in all branches, the maintenance of a high professional standard among its members, also the reading, discussion, and publication of professional papers, which are calculated to advance the science of Heating and Ventilation and aid in the interchange of experience among members.

## ARTICLE I.

Section 1. The officers of this Society shall consist of a President, two Vice-Presidents, Secretary, Treasurer and a Board of Governors, whose duties shall be as defined hereafter.

Section 2. The headquarters of this Society shall be located in the city of New York.

## ARTICLE II.

### MEETINGS.

Section 1. The annual meeting of the Society will be held in New York City in January of each year, the exact date to be fixed by the Board of Governors, sixty days in advance of the meeting. In addition to the annual meeting, a semi-annual meeting may be held during the summer months. The advisability of calling such meeting, and the place of holding the same, to be determined by the Board of Governors, at least sixty days before the date selected.

### QUORUM.

Section 2. Fifteen members present, at either annual or semi-annual meeting, shall constitute a quorum to do business.

## ARTICLE III.

### MEMBERSHIP.

Section 1. This Society shall be composed of members, junior members, associate members, and honorary members.

Section 2. An applicant for membership shall be a Heating or Ventilating Engineer or Expert, who has been professionally en-

gaged in the business of heating and ventilation for at least five years. Graduation from a school of engineering of recognized repute shall be considered as equivalent to two years of active practice, The applicant must be qualified to design as well as take charge of and direct the construction of heating and ventilating work in the branch which he has made his specialty. Mining, civil, electrical, mechanical, naval, or Government engineers or architects, who are, in the opinion of the Board of Governors, qualified by reason of their experience in designing or superintending the installation of heating and ventilating plants, may also become members.

Section 3. An applicant for junior membership must have been actively engaged in the work of heating and ventilating for three years, or be a graduate of a school of engineering of recognized repute, with at least one year's active practice in heating and ventilating work.

Section 4. Applicants for associate membership must have such knowledge of, or connection with the business of heating and ventilating, as to qualify them, in the opinion of the Board of Governors, to co-operate with heating and ventilating engineers, in the advancement of professional knowledge.

Section 5. The names of candidates for honorary membership shall only be presented at annual meetings, and they must have the unanimous endorsement of the full Board of Governors before their names are submitted to the meeting for ballot.

Section 6. All members, honorary members, juniors, and associates shall be equally entitled to the privileges of membership, excepting that honorary members, juniors and associates shall not be entitled to vote or hold any office in the Society.

Section 7. Juniors may become eligible for full membership.

## ARTICLE IV.

### ELECTION OF MEMBERS.

Section 1. Every candidate for admission to the Society, except a candidate for honorary membership, must be proposed by at least two members to whom he should be personally known, and his application must be seconded by two other members. The application for membership must be accompanied by a statement in writing, by the candidate, of the grounds of his application for election, including an account of his professional experience, together with an agreement that he will conform to the requirements of membership, if elected.

Section 2. All applications for membership are to be sent to the Secretary, and acted upon by the Board of Governors, at its first meeting thereafter. The Secretary shall mail to each member of the Society, in the form of a letter ballot, the names of candidates who are recommended by the Board of Governors for election, together with a statement of their qualifications, and the names of their proposers and seconders.

Section 3. Any member entitled to vote may erase the name of any candidate for membership from the ballot, should he wish to vote against his admission. All names not erased will be counted as affirmative votes. The ballot is to be enclosed in two envelopes, the inner one to be blank, and the outer one endorsed by the member voting, and returned to the Secretary within thirty days of its date.

Section 4. The said blank envelopes shall be opened by the Board of Governors at the first meeting after the thirty days have expired, and the candidates elected shall be notified at once, and their names announced at the ensuing meeting of the Society, and also incorporated in the first ensuing list of members. The names of candidates not elected shall neither be recorded nor announced in the proceedings.

Section 5. When seven votes shall be cast against any candidate, his election shall be defeated.

Section 6. Any person who shall be elected to membership in the Society shall be promptly notified of the fact by the Secretary, and he shall accept such election, subscribe to the rules of the Society, and pay the initiation fee within three months after such notice of election shall have been sent him, or his election shall be void.

Section 7. The name of any rejected candidate may, after three months from date of such rejection, again he presented to the Board of Governors, and if reconsideration is granted, another ballot shall be ordered, at which twelve negative votes shall be required to defeat the candidate.

Section 8. Junior members desiring to become full members shall make application to the Board of Governors, who shall consider the reasons advanced for the change in membership, and if found satisfactory, a favorable vote of the majority of said Board of Governors shall be cufficient to authorize the transfer.

## ARTICLE V.

### INITIATION FEES AND DUES.

The initiation fees of members and associates shall be fifteen dol-

lars, payable upon notification of their election. Their annual dues shall be ten dollars, payable in January of each year in advance or at the date of their election to membership. Members elected prior to July in each year shall pay full dues for that year. Members elected after July 1st shall pay half dues for the year in which they are elected.

The initiation fees for juniors shall be ten dollars, and the annual dues ten dollars, payable as per form required of members. Junior members promoted to full membership shall pay, upon notification of transfer, an initation fee of five dollars.

## ARTICLE VI.

### OFFICERS.

Section 1. The President shall preside at all meetings of the Society, and exercise general supervision over its interests and welfare. He shall also be, by virtue of his office, Chairman of the Board of Governors. He shall have power to call special meetings of the Board of Governors, if in his judgment the needs of the Society require it, and he shall call special meetings of the Board of Governors when so requested by three members of such Board of Governors, or if requested in writing by ten members of the Society. He shall appoint all committees not otherwise provided for in these by-laws, or by resolutions constituting said committees. He or the Vice-Chairman shall, with the Treasurer, sign all checks, written contracts, or other financial obligations of the Society authorized by the Board of Governors, and he shall be *ex-officio* member of all standing committees.

Section 2. In the absence of the President from any meeting, either Vice-President shall be vested with all the powers of the President. In the absence of both the President and Vice-Presidents, the meeting shall elect a temporary presiding officer, from the members present; the Secretary calling for a vote.

Section 3. The Secretary shall be present at all meetings of the Society and of the Board of Governors, and keep the minutes thereof. He shall conduct the routine correspondence, receive all communications addressed to the Society, and present the same to the Society or to the proper committees. He shall issue notices of all meetings, promptly inform committees of their appointment, and officers and new members of their election. He shall keep a complete list of members with their addresses and dates of election, and shall send a copy thereof annually to each member. He shall perform

such other duties pertaining to his office as shall be imposed upon him by the Society or the Board of Governors, and shall receive a salary to be fixed by the Board of Governors.

Section 4. The Treasurer shall collect and have charge of all funds and shall deposit same to the credit of the Society in such depository as may be designated by the Board of Governors. He shall pay all bills, duly approved, and shall keep book accounts of all his receipts and expenditures, which shall be at all times open to inspection by the Board of Governors. He shall present, at each annual meeting of the Society, a written statement showing the receipts and expenditures during the previous year; which statement must be duly audited by an Auditing Committee, to be appointed by the Board of Governors, at the annual meeting. He shall make reports to the Board of Governors as to the financial standing of the Society at any time they may call for it, provided not less than three days' notice shall have been given. He shall give bonds for the faithful performance of his duties, in such amount and with such securities as the Board of Governors may require; the premium to be paid by the Society.

Section 5. The Board of Governors shall consist of five members of the Society, in addition to the President and Secretary, making the full number seven persons. They shall have the supervision and care of all the property of the Society, and shall manage and conduct its affairs in accordance with the charter and by-laws. They shall hold stated meetings at least once every two months, and special meetings at the written request of three members of the Board, or upon the call of the President or Vice-Chairman. Four members of the Board of Governors shall constitute a quorum. They shall present, at every annual meeting of the Society, a general statement of its proceedings during the year, and a report on the condition of the Society. They shall fill any vacancy occurring among the officers of the Society. The Board of Governors shall, at the first session of the annual meeting, appoint from the active members three auditors, to examine and certify the accounts of the Treasurer. They shall also appoint the Nominating Committee of five members. This latter to be appointed at least four months before the date of the annual meeting. No officer of the Society shall be eligible to any of these appointments. The Board of Governors shall meet for organization within ten days from the annual meeting, when from among their number they shall elect a Vice-Chairman, and the President shall appoint the following committees,

consisting of three members each: Finance, Membership, and Publication.

The Finance Committee shall have charge of the financial affairs of the Society, and shall approve in writing all expenditures authorized by the Board of Governors.

The Membership Committee shall receive all applications for membership, make rigid inquiry as to the eligibility of candidates, and report to the Secretary only such as have been approved. In case of disapproval, only the proposers of the application shall be notified of such action. The proceedings of this committee shall be private and confidential.

The Publication Committee shall receive and examine all papers for presentation to the Society, and accept for publication such as it may approve. It shall publish during each year the proceedings of the Society, containing the papers and discussions so approved, and abstracts of the minutes of the Society and Board of Governors. No member shall publish any paper as having been read before the Society without obtaining the consent of this committee, and such permission shall not be construed to be an endorsement by the Society of any statements advanced in such papers or publications. The Publication Committee is to be in charge of all books, periodicals and drawings, and similar property belonging to or loaned to the Society.

These standing committees shall be guided by such rules and regulations as the Board of Governors shall from time to time prescribe.

Any member of the Board of Governors who shall absent himself for three consecutive stated meetings of the Board, without an excuse satisfactory to the Board, shall cease to be a member thereof, and the Board shall proceed to fill his place for the unexpired term; due notice of such action shall be sent him.

## ARTICLE VII.

### ELECTION OF OFFICERS.

Section 1. The Nominating Committee, appointed by the Board of Governors, shall consist of five members, whose duty it shall be to select the candidates for the various offices that are to be filled at the next ensuing annual meeting. This committee shall present to the Secretary, at least sixty days before the date of the annual meeting, the names of two candidates for each office to be voted for, first securing the consent of the members selected to stand for the election.

Section 2. Upon receipt of the list of nominations from the Nom-

inating Committee, the Secretary shall at once prepare the ballots and forward them to the members thirty days before the date of the annual meeting.

Section 3. Each member entitled to vote shall erase the names of all candidates for whom he does not wish to vote, and return his vote so that it shall reach the Secretary before the date of the annual meeting. The ballot is to be enclosed in two envelopes, the inner one to be blank and the outer one endorsed by the voter. The votes of members in arrears for more than one year's dues shall not be counted.

Section 4. The vote shall be opened at the annual meeting by three tellers to be appointed by the President, and the candidates receiving the highest vote for the several offices shall be declared elected.

Section 5. Whenever, by resignation or otherwise, there shall be a vacancy in any office between the dates of the annual meetings, the Board of Governors shall have the power to fill such office for the balance of the term.

## ARTICLE VIII.

### RESIGNATIONS, EXPULSIONS, ETC.

Section 1. Any member, whose dues are paid in full, may resign at any time. Resignations must be presented in writing, to the Board of Governors, who shall act on them at their first meeting following their receipt.

Section 2. Any member whose dues shall remain unpaid for one year shall forfeit the privileges of membership, and if he neglects or refuses to pay his dues within thirty days after notification from the Secretary, his name may be stricken from the roll of members by a majority vote of the Board of Governors.

Section 3. At the end of each fiscal year, the Secretary shall strike from the roll the names of such members as are in arrears for two years' dues to the Society, and shall report the same to the Society at its next annual meeting.

Section 4. Any member may be expelled for conduct on his part likely, in the opinion of the Society, to endanger its welfare, interests, or character; provided, however, that charges have been made to the Board of Governors, by a member of the Society in good standing, and that the Board of Governors have, after investigation and opportunity for defense, recommended such expulsion.

Section 5. Any person ceasing to be a member of the Society,

through resignation or otherwise, shall forfeit all right, title and interest in the property of the Society.

## ARTICLE IX.

### SOCIETY'S ENDORSEMENT.

Recommendation, endorsement or approval shall not be given to or made for any individual, firm, association or corporation, nor for any scientific, literary, mechanical or engineering production. The opinion of the Society may, however, be expressed on subjects affecting the public welfare, provided that this opinion does not carry with it the promotion of the interests of any individual, firm, association or corporation.

## ARTICLE X.

### AMENDMENTS.

Proposed amendments to this Constitution must be presented in writing to the Board of Governors, signed by at least three members. The Board of Governors shall have copies of the proposed amendment sent to all members, together with the reasons presented why it is thought desirable by the members presenting same, that the change should be made. The question of its adoption shall be voted upon by letter ballot in the manner prescribed for election of members. If two-thirds of the votes cast are in favor of the proposed amendment, it shall be adopted.

## ARTICLE XI.

### ORDER OF BUSINESS.

1. Roll Call.
2. Reading of minutes of previous meeting.
3. Report of officers—President, Secretary, Treasurer.
4. Report of the Board of Governors.
5. Reports of standing and special committees.
6. Unfinished business.
7. Report of tellers of annual election.
8. New business.
9. Reading of papers and discussions.

### PARLIAMENTARY RULES.

In all questions arising at any meeting, involving parliamentary rules not provided for in this Constitution, "Cushing's Manual' shall be the governing authority.

## MEMBERSHIP OF THE SOCIETY.

### 1899.

#### MEMBERS.

George E. Adams.....Glens Falls, N. Y.
Henry Adams, 721 Equitable Bldg., *Pres., 1899*....Baltimore, Md.
Homer Addams, 731 Turner St.....Allentown, Pa.
Juan A. Almiral, 44 Dey St.....New York City.
Newell P. Andrus, 524 Macon St.....Brooklyn, N. Y.
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